JOURNAL OF AGRICULTURAL RESEARCH

VOL. 36 WASHINGTON, D. C., FEBRUARY 15, 1928 NO. 4

CHEMICAL COMPOSITION OF APPLE JUICES AS AFFECTED BY CLIMATIC CONDITIONS [1]

By JOSEPH S. CALDWELL

Physiologist, Office of Horticulture, Bureau of Plant Industry, United States Department of Agriculture

PURPOSE OF THE WORK

Students of climatology in its relation to the growth of crops have confined their studies to annual plants, and there are in the literature no reports of work in which perennials growing under controlled cultural conditions have been studied for long periods in an attempt to ascertain whether annual variations in climatic conditions affect the chemical composition of the fruit in a definite and consistent fashion. An earlier paper from this laboratory (*11*)[2] reports an investigation of this question, employing grapes as experimental material, in which it has been shown that the chemical composition of the fruit of a large group of varieties shows from year to year consistent and sustained response to the annual fluctuations in the intensity of certain climatic factors. The results are such as to suggest that the composition of the annual crop is a physiological response of the plant to climatic factors of the environment of such fundamental character that large groups of horticultural varieties of widely dissimilar character exhibit identical behavior. The present paper reports the result of an investigation begun concurrently with that upon grapes, in which a large collection of apples has been studied for a period of six years in an attempt to ascertain whether the composition of the fruit from year to year is in any degree a reflection of the climatic conditions prevailing during its development.

In order that an experiment of this character may be at all conclusive, certain conditions must be met at the outset. The nonclimatic factors, such as physical and chemical character of soil, slope, and exposure, must be as uniform as possible, and there must be a past and present history of uniformity in treatment, cultural and otherwise, of the experimental material, and an assurance of the continuance of such likeness of treatment throughout the experiment. With these conditions assured, any experiment of this character gains greatly in value if the experimental material used be as widely varied in character as it is possible to procure, in order that a wide range of individual variations may be encountered. If a fundamental physiological response of the organism to environmental factors really occurs, it should break through all the minor phenomena resulting from causes inherent in or peculiar to individuals and manifest itself as mass behavior. The more heterogeneous the assemblage of individuals for such an experiment can be made, the more significance can be attached to any clear-cut evidence that the assemblage is acting as a unit.

[1] Received for publication July 28, 1926; issued April, 1928. This paper is the third in a series of studies on fruit juices. References to the earlier papers in the series are given in "Literature cited" (*10, 11*).

[2] Reference is made by number (italic) to "Literature cited," p. 364.

MATERIAL EMPLOYED

The collection of apple varieties maintained by the Office of Horticulture of the Bureau of Plant Industry at the Arlington Experiment Farm, Rosslyn, Va., near Washington, D. C., offers an exceptional opportunity for such a study. The collection contains about 600 varieties, there being two or occasionally four trees of a variety, most of the trees being 11 to 14 years of age at the time the work was begun. Most of the varieties which have attained commercial importance in any of the producing districts of the United States are represented, and in addition the collection has a very large number of the older sorts which have been restricted to home orchards or which have been displaced in commercial orchards. In addition, there is a considerable number of varieties of diverse origin under test by the Office of Foreign Plant Introduction and a number of French cider apples propagated from the collection brought from France by W. B. Alwood (*4*).

From this collection a list of 100 varieties was selected in 1919. The number was determined by necessity rather than by choice, since the time available for the analytical work was limited. In selecting the varieties to be used an attempt was made to include only trees apparently in good condition, free from evidence of serious disease, and with a history of regular bearing of crops of fairly uniform size. From the list of varieties meeting these requirements an attempt was made to select 100 which would represent the greatest possible range in dessert and culinary quality and in chemical composition. Preliminary analyses made in 1918 and 1919, published analyses, descriptions of varieties in horticultural literature, and information furnished by associates in the Office of Horticulture were utilized as guides in making up the final selections. Analyses were made upon the members of this list, in so far as they were in fruit, in 1920 and 1921. From the experience of these two years it was realized that for various reasons not more than 70 to 75 per cent of the group would be in fruit in any one year and that enlargement of the numbers employed was therefore desirable. As the analytical data to be obtained were necessary as a background for other investigations, in progress or projected (*12*), additional time was devoted to the work and the original list of 100 varieties was increased to 250 in 1921. It remained at that number for the last four years of the work. Not more than 202 of this number were analyzed in any one year, and 32 are not included in the analytical results for various reasons. Some proved to be irregular in bearing, or bloomed so early that frost injury was of frequent occurrence. Death of trees and disease or injury of one of the pair of trees of a variety necessitated the dropping of others, since the material for analysis was always a mixed sample taken from the two trees of the variety, and no sample was taken when only one tree of the variety was in fruit. These causes, with partial destruction of the crop by frost in two years and the nearly universal habit of apple trees of occasionally failing to fruit without discoverable reason, resulted in considerable irregularity in the number of varieties analyzed from year to year.

In the final tabulation of the results no variety of the original list of 100 is included unless it bore fruit in four of the six years of the test; of the 150 varieties added in 1922, none is included unless it fruited in three of the four years following its addition to the list.

The general results are consequently free from the error which would result from inclusion of data derived from occasional crops borne by varieties with the alternate bearing habit.

The following statement as to the orchard location, soil, cultural treatment, and general handling of the trees has been prepared by H. P. Gould, of the Office of Horticulture; who has had direct supervision of the orchard during the work.

THE VARIETY APPLE ORCHARD AT ARLINGTON EXPERIMENT FARM

The entire orchard at the Arlington Experiment Farm, excepting certain seedling trees in one section, consists of trees propagated at the farm as piece-root grafts and grown there during their nursery period. The stocks used were ordinary commercial French crab seedlings. The scions came from a great number of sources. The late W. N. Irwin, for many years a member of the pomological staff of the department, first in the Division of Pomology and later in the Office of Pomological Investigations, supplied scions of more varieties than were obtained from any other one source. These were taken from a private variety collection which he had assembled from many sources during a period of several years, and which he had propagated and grown practically under nursery conditions on a piece of land located in the outskirts of Washington. Scions of many varieties were obtained from the New York Experiment Station at Geneva. Others came from many and widely diverse sources. The trees were grown in the nursery at Arlington farm during two seasons in most if not all cases and were planted as 2-year-olds.

The site occupied by the orchard at the Arlington farm varies somewhat in topography. A portion is level in the main, while certain sections are described as rolling. In the latter the slopes in general are east and west, though in certain areas the aspect is north. However, the slopes are not sufficient to influence the orchard materially except as they may result in better soil and atmospheric drainage than would otherwise prevail. The times of blossoming and ripening are probably not influenced in any degree by the topography, as the circulation of air throughout the orchard is unimpeded and is influenced but little if any by the irregularities of contour.

The soil is naturally a rather heavy reddish clay with a clay subsoil. Most of the farm, presumably including also the site of the orchard, is underlain at a depth of 3 or 4 feet with a tight impervious "pipe clay." While comparatively little of the site suffers seriously from lack of soil drainage, due probably to its more or less rolling topography, there are certain areas where the water stands at times for a considerable period. A few of the trees have suffered as a result. The constant use of soil-improvement crops and the application of manure on the poorer areas have materially improved the physical condition of the surface, so that, although normally a rather stiff clay, it has become somewhat loamy because of the humus that has been added.

The oldest portion of the orchard was planted in the spring of 1905. Additional smaller plantings were made in 1906 and 1909 and at various times up to 1911.

The management of the orchard up to about 1915 followed in a routine way an ordinary farm orchard plan of maintenance that involved tillage, cover crops, spraying, and pruning. Stable manure has been used from time to time on some of the poorer spots. Since 1915 the same general plan of maintenance has been followed, but the system of pruning has been subject to considerable modification from time to time; at times little or no pruning has been done, at other times the pruning has been unwise and doubtless harmful in its effects.

Since about 1921 the orchard has been sprayed in accordance with good commercial orchard practice so far as the schedule of applications is concerned. In most seasons during this time the applications have been fairly effective, considering the inherent difficulties in spraying a variety orchard.

In the spring of 1924 the trees received phosphoric acid and nitrate of soda at the general rate of 5 pounds of each to the tree. In the spring of 1925 the trees were given 5 pounds of nitrate of soda only. Since 1918 the older part of the orchard has been in sod. The grass has been cut once or twice during the season and left on the ground where it fell. The rest of the orchard has been cultivated more or less, usually with some cover crop on the land during the season.

The general plan of operation in recent years has aimed to maintain the orchard as nearly as possible on the plan of the well-kept farm orchard, no attempt being made to stimulate the trees to maximum production.

PHENOLOGICAL DATA

Detailed records as to dates of blooming of the varieties have not been regularly made during the period covered by the work here reported. Such records were taken in 1919, 1924, and 1925, but were not made in the intervening years. A fairly trustworthy estimate can be obtained from the records of the various orchard operations at the Arlington farm, which include a record of the dates at which the various spray applications were made. The calyx spray is usually applied when the petals have fallen from all but the latest blooming varieties, and the date upon which its application begins practically coincides with the end of the blooming period.

Thus in 1919 blooming was beginning April 17, was at its height April 22, and was practically over on April 30. Spraying was begun April 30 and continued through May 4. In 1920 no blooming records were kept, but spraying was begun on May 9, or 10 days later than in 1919. In 1921, 1922, and 1923 spraying was begun, respectively, on May 2, April 29, and April 30, indicating that the blooming period in these years was very nearly identical with that of 1919. In 1924 detailed records indicate that blooming began April 24, reached its height about May 3, and was practically over on May 8. Spraying was begun on May 9. In 1925 the blooming records give April 12 to 25 as the period in which the great majority of varieties came into bloom. Spraying was begun on April 25.

Summarizing, it appears to be a close approximation to the facts to say that in 1921, 1922, and 1923 the blooming period was largely included in the period April 15 to 30; that in 1925 it occurred about five days earlier, or from April 10 to 25; and that in 1920 and 1924 it was decidedly late, extending from about April 24 to May 8. The last half of April is probably the normal blooming period in this latitude for the great majority of the varieties present in the orchard, 1925 having been a year of early bloom while in 1920 and 1924 blooming was quite late. These seasonal variations in date of blooming are reflected in a broad general way in the dates of picking for the various years, which are in the majority of cases distinctly later in 1920 and 1924. The dates of picking of the samples are in all cases stated in the table giving the analytical data. (See Table 1.)

METHODS OF TAKING SAMPLES

The fruit employed for analysis was in all cases a tree-run sample of the crop of the variety, taken at the time the variety was harvested. In the great majority of instances the entire crop of the pair of trees was picked at one time, but in some of the early-maturing varieties two or rarely three pickings were occasionally made. In these cases the sample was taken from the picking which included the bulk of the crop. From the unsorted tree-run fruit of each variety a quantity ranging from 2 to 10 bushels (the quantity depending upon the size of the crop and the demand for that variety for use in other work) was delivered to the laboratory immediately after picking and there stored until used. The stage of maturity attained at picking was that known among orchardists as "market ripe," as determined by the judgment of an experienced orchard foreman conversant with the varieties present in the orchard.

As received at the laboratory the fruit was stored in lug boxes in a concrete-walled basement room and there held until it had reached the condition of cider ripeness; that is, a condition midway between picking ripeness and dessert ripeness. Fruit in this stage has attained the full flavor and bouquet of the variety, has begun to soften very slightly, but is still too firm for eating out of hand. The temperatures in the storage room fluctuated with the outside temperature, remaining 8° to 10° F. below it, so that the time that fruit remained in storage prior to pressing varied with season, variety, and degree of ripeness when received, but is indicated in every case by inclusion in the analytical data of the dates of picking and of pressing.

It was usually the case toward the end of the apple harvest that a large number of varieties were picked practically at one time. In these cases the fruit was taken directly from the orchard into cold storage and there held until the end of the picking season It was then transferred to the basement storage room already mentioned, where it remained until it attained the proper condition for pressing.

That there should be some variation in the degree of maturity attained both at picking and at pressing as a result of errors in judgment is inevitable. It is believed that such errors are reduced to a minimum by the fact that the same individuals handled all samples at pressing throughout the work.

The entire lot of any variety was always pressed together, without discarding any specimens except those partially decayed. The samples were pressed without washing in order to avoid dilution of the juice, and a sufficient number of clean, dry press cloths were provided to permit of their use only once before washing and drying. In most of the work pressing was done in a power-operated hydraulic press, but a smaller hand-operated press was also used, mainly for smaller lots. The smaller press had been so modified as to make possible as good an extraction of juice as was obtained with the power press, and care was taken to assure such extraction.

All the juice from a variety was received in a large vessel, and samples for analysis were immediately taken, the juice being thoroughly stirred meanwhile to obtain uniformity. The analyses were begun immediately and were always completed on the same day the juice was pressed. In all cases samples of the juice were taken in triplicate or quadruplicate and preserved by Pasteurization. Most of these Pasteurized samples were subsequently analyzed in connection with the studies of the effect of Pasteurization in progress concurrently with the present work. The results of the second analyses incidentally serve as a general check upon the accuracy of the first, and have consequently made possible the omission from the tabulated results of a few analyses in which errors had obviously occurred.

ANALYTICAL METHODS

In 1920 and 1921 the only determinations made upon the fresh juices were those of titratable acidity, free reducing sugars, and total sugars after inversion. In 1922 and subsequently these were supplemented by determinations of total astringency and astringent nontannins. Determinations of total solids in juices were occasionally but not regularly made.

Determinations of total titratable acidity were made by titration with N/10 sodium hydroxide against phenolphthalein as indicator, after dilution of the juice with 10 volumes of distilled water.

Determinations of free reducing sugars were made by the Munson and Walker method, employing neutral lead acetate for clarification, and potassium oxalate for removing the surplus lead. The cuprous oxide was dissolved in ferric ammonium sulphate and titrated with N/20 $KMnO_4$.

Total sugars were determined upon a portion of the clarified solution by inverting with HCl and employing the same method as for reducing sugars.

Determinations of total astringency were made by the Loewenthal-Proctor method, titrating the diluted juice with N/20 $KMnO_4$ in presence of indigo carmine. Astringent nontannins were determined in the same way after removal of tannins by precipitation with gelatin and filtration with kaolin. The results are expressed in terms of the conventional tannin factor.

TABLE 1.—*Analytical results for the juices of 216 varieties of apples analyzed in three to six of the years 1920–1925*

Variety	Date picked	Date of analysis	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar after inversion	Acid as malic	Total astringency	Tannin	Nontannin astringency	Total solids
Fruiting 6 years:										
Baker	Sept. 14, 1920	Oct. 7	9.18	0.18	9.36	0.684	------	------	------	------
	Aug. 23, 1921	Sept. 27	8.96	2.44	11.40	.718	------	------	------	------
	Sept. 25, 1922	Nov. 15	7.88	4.08	11.96	.590	0.0823	0.0385	0.0438	15.32
	Sept. 24, 1923	Oct. 6	8.54	4.74	13.28	.419	.0961	.0386	.0575	16.13
	Oct. 1, 1924	Oct. 9	7.58	4.56	12.14	.555	.1122	.0360	.0762	------
	Sept. 17, 1925	Oct. 6	6.48	3.49	9.97	.542	.0903	.0361	.0542	12.42
Celestia	Oct. 5, 1920	Oct. 18	8.76	2.13	10.89	.606	------	------	------	13.09
	Aug. 18, 1921	Oct. 3	6.91	2.61	9.52	.585	------	------	------	------
	Sept. 27, 1922	Dec. 8	8.39	1.46	9.85	.551	.0918	.0169	.0749	13.11
	Sept. 16, 1923	Sept. 29	8.30	3.33	11.63	.588	.0650	.0150	.0500	13.63
	Oct. 14, 1924	Oct. 16	8.31	2.23	10.54	.353	.0660	.0180	.0480	------
	Sept. 10, 1925	Sept. 23	9.40	2.56	11.96	.384	.0858	.0323	.0533	14.84
Collins	Oct. 15, 1920	Oct. 28	9.50	2.50	12.00	.650	------	------	------	13.51
	Sept. 2, 1921	Sept. 19	8.64	2.43	11.07	.802	------	------	------	------
	Sept. 30, 1922	Nov. 1	7.52	1.54	9.06	.680	.0872	.0265	.0607	11.46
	Oct. 26, 1923	Oct. 31	7.35	5.15	12.50	.740	.1112	.0222	.0890	------
	Oct. 28, 1924	Nov. 4	6.08	3.34	9.42	.517	.0995	.0295	.0700	------
	Oct. 7, 1925	Nov. 23	7.82	2.56	10.38	.372	.1058	.0373	.0685	11.57
Indian	Oct. 15, 1920	Nov. 3	7.18	1.30	8.48	.522	------	------	------	9.77
	Sept. 2, 1921	Oct. 8	8.96	2.99	11.95	.561	------	------	------	------
	Oct. 7, 1922	Oct. 24	7.70	2.35	10.05	.461	.1380	.0469	.0911	12.28
	Oct. 8, 1923	Oct. 18	8.08	3.00	11.08	.590	.1055	.0352	.0703	13.52
	Nov. 4, 1924	Nov. 13	8.58	2.44	11.02	.419	.1715	.0743	.0972	------
	Oct. 16, 1925	Nov. 18	7.26	2.30	9.56	.318	.1380	.0440	.0940	11.05
Jefferis	Aug. 14, 1920	Sept. 21	8.12	1.09	9.21	.510	------	------	------	11.25
	Aug. 1, 1921	Sept. 5	7.96	2.62	10.58	.607	------	------	------	------
	July 27, 1922	July 31	7.52	1.04	8.56	.808	.1481	.0418	.1063	10.69
	Aug. 23, 1923	Aug. 30	8.15	5.21	13.36	.642	.1165	.0568	.0597	14.87
	Aug. 29, 1924	Sept. 6	7.98	3.30	11.28	.342	.1050	.0735	.0315	------
	Aug. 8, 1925	Aug. 15	8.24	3.53	11.77	.568	.1010	.0497	.0513	------
Nero	Oct. 1, 1920	Oct. 20	9.01	2.19	11.20	.294	------	------	------	14.32
	Aug. 24, 1921	Sept. 18	8.45	3.29	11.74	.460	------	------	------	------
	Sept. 30, 1922	Oct. 27	8.98	3.52	12.50	.292	.1123	.0238	.0885	13.67
	Oct. 26, 1923	Nov. 1	9.64	2.97	12.61	.363	.1320	.0590	.0730	15.80
	Oct. 28, 1924	Dec. 1	8.55	1.85	10.40	.285	.1255	.0247	.1008	------
	Oct. 1, 1925	Oct. 29	7.67	2.25	9.92	.254	.1165	.0595	.0570	12.37

TABLE 1.—*Analytical results for the juices of 216 varieties of apples analyzed in three to six of the years 1920–1925*—Continued

Variety	Date picked	Date of analysis	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar after inversion	Acid as malic	Total astringency	Tannin	Non-tannin astringency	Total solids
Fruiting 6 years—Continued.										
Northwestern Greening.	Oct. 1, 1920	Nov. 1	8.48	2.21	10.69	0.500				13.41
	Sept. 30, 1921	Oct. 24	8.69	2.51	11.20	.678				
	Oct. 7, 1922	Oct. 12	7.84	2.56	10.40	.368	0.0938	0.0430	0.0508	13.45
	Sept. 28, 1923	Nov. 12	8.36	2.21	10.57	.420	.1174	.0617	.0557	14.28
	Nov. 4, 1924	Nov. 15	8.12	1.09	9.21	.339	.0878	.0278	.0600	
	Oct. 5, 1925	Nov. 24	9.16	1.75	10.91	.378	.0735	.0177	.0558	12.84
Ohio Pippin	Sept. 10, 1920	Sept. 30	8.01	1.58	9.59	.448				
	Sept. 24, 1921	Oct. 11	7.82	1.27	9.09	.482				
	Sept. 6, 1922	Sept. 16	6.77	4.80	11.57	.332	.0704	.0122	.0582	
	Oct. 4, 1923	Nov. 6	7.36	4.38	11.74	.314	.0865	.0300	.0565	14.40
	Oct. 1, 1924	Oct. 8	7.50	4.72	12.22	.409	.1030	.0342	.0688	
	Oct. 12, 1925	Oct. 23	5.82	3.76	9.58	.222	.0938	.0428	.0510	11.93
Walbridge	Nov. 1, 1920	Nov. 20	8.86	2.02	10.88	.610				12.87
	Sept. 13, 1921	Oct. 16	8.64	2.77	11.41	.571				
	Sept. 26, 1922	Sept. 29	8.10	1.52	9.62	.680	.1034	.0591	.0443	13.14
	Oct. 20, 1923	Oct. 25	10.40	2.96	13.36	.535	.1052	.0452	.0600	15.16
	Sept. 13, 1924	Oct. 9	8.90	1.24	10.14	.660	.1225	.0445	.0780	
	Sept. 23, 1925	Nov. 3	6.77	1.23	8.00	.412	.0977	.0432	.0545	10.87
Fruiting 5 years:										
Akin	Sept. 11, 1921	Oct. 6	8.64	3.31	11.95	.465				
	Oct. 27, 1922	Dec. 5	8.43	2.03	10.46	.432	.1099	.0613	.0486	14.28
	Oct. 20, 1923	Oct. 25	9.46	3.20	12.66	.391	.0951	.0557	.0394	14.58
	Oct. 8, 1924	Oct. 17	7.68	1.82	9.50	.384	.0815	.0310	.0505	
	Oct. 15, 1925	Oct. 31	8.48	2.80	11.28	.314	.0772	.0212	.0560	13.56
Arkansas Black	Oct. 12, 1920	Nov. 3	7.42	3.16	10.58	.513				
	Sept. 23, 1921	Oct. 16	8.21	3.27	11.48	.625				
	Sept. 23, 1922	Dec. 1	8.50	1.84	10.34	.536	.0747	.0273	.0474	12.97
	Sept. 28, 1923	Dec. 3	7.18	2.56	9.74	.439	.0930	.0374	.0556	13.92
	Oct. 7, 1925	Nov. 24	9.02	2.44	11.46	.360	.0925	.0325	.0600	12.82
Baldwin	Oct. 11, 1920	Nov. 2	8.72	1.39	10.11	.630				12.96
	Oct. 3, 1922	Oct. 5	7.36	3.17	10.53	.571	.0885	.0324	.0561	
	Oct. 26, 1923	Oct. 31	9.40	5.56	14.96	.635	.1346	.0465	.0881	16.02
	Oct. 20, 1924	Oct. 30	7.24	4.24	11.48	.430	.1237	.0259	.0978	
	Sept. 16, 1925	Oct. 6	6.76	3.43	10.19	.424	.0953	.0343	.0610	
Barry	Aug. 24, 1920	Sept. 8	8.05	1.71	9.76	.923				
	Aug. 24, 1921	Sept. 11	7.42	3.84	11.26	.905				
	Aug. 6, 1922	Aug. 10	7.51	1.10	8.61	1.337	.1359	.0297	.1062	10.18
	Aug. 23, 1923	Sept. 12	6.25	2.47	8.72	.905	.1210	.0320	.0890	9.71
	Sept. 13, 1924	Oct. 3	5.73	1.71	7.44	.750	.0910	.0233	.0677	
Black Ben	Oct. 25, 1920	Nov. 11	7.11	2.57	9.68	.475				
	Sept. 26, 1922	Oct. 26	6.32	1.94	8.26	.520	.1042	.0243	.0799	11.24
	Sept. 27, 1923	Dec. 3	7.38	2.86	10.24	.449	.1110	.0470	.0640	14.32
	Nov. 4, 1924	Nov. 20	6.56	2.58	9.14	.368	.0920	.0380	.0540	
	Oct. 8, 1925	Oct. 19	8.28	1.13	9.41	.455	.0975	.0240	.0735	14.12
Brackett	Oct. 27, 1920	Nov. 18	7.93	1.48	9.41	.496				10.58
	Sept. 11, 1921	Nov. 6	6.82	2.59	9.41	.537				
	Oct. 11, 1922	Oct. 21	7.11	2.47	9.58	.325	.1115	.0469	.0646	11.40
	Oct. 26, 1923	Oct. 30	9.42	2.78	12.20	.480	.1125	.0244	.0881	14.30
	Nov. 1, 1924	Nov. 8	8.66	2.06	10.72	.408	.1124	.0387	.0737	
Buckskin	Sept. 15, 1920	Oct. 6	7.02	2.19	9.21	.546				11.35
	Aug. 24, 1921	Oct. 3	8.16	2.75	10.91	.707				
	Sept. 18, 1922	Sept. 20	6.82	2.43	9.25	.532	.0790	.0252	.0538	12.53
	Oct. 20, 1923	Oct. 27	8.00	5.20	13.20	.650	.1112	.0400	.0712	15.55
	Oct. 11, 1924	Oct. 13	7.07	2.00	9.07	.502	.1295	.0463	.0832	11.54
Bugborn	Aug. 18, 1921	Sept. 29	8.11	4.08	12.19	.508				
	Sept. 23, 1922	Nov. 13	8.04	3.05	11.09	.355	.1141	.0477	.0664	13.04
	Sept. 23, 1923	Oct. 1	8.54	2.79	11.33	.540	.1070	.0438	.0632	13.79
	Sept. 15, 1924	Oct. 2	6.90	2.46	9.36	.510	.1195	.0515	.0680	
	Sept. 25, 1925	Nov. 3	8.06	1.26	9.32	.315	.1165	.0359	.0806	12.98
Doctor	Sept. 25, 1920	Nov. 7	8.09	1.32	9.41	.522				
	Sept. 2, 1921	Oct. 16	9.16	2.04	11.20	.600				
	Oct. 30, 1922	Nov. 6	6.32	2.08	8.40	.545	.0377	.0114	.0263	10.16
	Oct. 8, 1923	Nov. 21	8.49	2.90	11.39	.507	.0852	.0262	.0590	16.24
	Oct. 11, 1924	Oct. 21	7.06	2.08	9.14	.482	.0540	.0172	.0368	

TABLE 1.—*Analytical results for the juices of 216 varieties of apples analyzed in three to six of the years 1920–1925*—Continued

Variety	Date picked	Date of analysis	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar after inversion	Acid as malic	Total astringency	Tannin	Non-tannin astringency	Total solids
Fruiting 5 years—Continued.										
Entz	Nov. 5, 1920	Nov. 29	10.88	1.49	12.37	1.037				13.91
	Sept. 6, 1921	Oct. 30	7.64	1.50	9.14	1.080				
	Sept. 18, 1922	Nov. 16	7.26	2.46	9.72	1.117	0.3460	0.2313	0.1147	16.04
	Sept. 5, 1923	Sept. 18	5.26	2.94	8.20	1.425	.2830	.1347	.1483	11.90
	Sept. 26, 1924	Oct. 14	6.06	3.21	9.27	1.375	.4130	.2010	.2120	
Evening Party	Sept. 15, 1920	Oct. 6	9.48	1.62	11.10	.276				13.83
	Sept. 2, 1921	Oct. 4	9.90	2.06	11.96	.308				
	Oct. 3, 1922	Oct. 7	6.90	3.12	10.02	.330	.0912	.0368	.0544	13.08
	Sept. 27, 1923	Nov. 2	10.16	4.02	14.18	.272	.1242	.0497	.0745	17.08
	Oct. 11, 1924	Oct. 14	7.41	3.28	10.69	.335	.1187	.0459	.0728	
Granny Smith	Nov. 1, 1920	Nov. 13	10.68	1.81	12.49	.731				13.90
	Sept. 13, 1921	Oct. 7	9.16	2.36	11.52	.708				
	Oct. 26, 1922	Oct. 31	7.38	6.27	13.65	.644	.0947	.0275	.0672	14.97
	Nov. 8, 1923	Nov. 12	6.88	3.36	10.24	.520	.0942	.0480	.0462	12.64
	Oct. 28, 1924	Dec. 2	7.27	3.71	10.98	.691	.1150	.0550	.0600	
Hilaire	Aug. 18, 1921	Oct. 16	8.79	5.18	13.97	.838				
	Sept. 28, 1922	Dec. 8	9.70	1.34	11.04	.817	.1474	.0677	.0797	14.47
	Sept. 28, 1923	Oct. 9	9.13	2.71	11.84	.890	.1045	.0393	.0652	15.18
	Sept. 23, 1924	Oct. 4	8.53	2.13	10.66	.799	.1355	.0798	.0557	
	Sept. 25, 1925	Oct. 29	8.70	1.54	10.24	.437	.0912	.0401	.0511	12.93
Hubbardston	Sept. 3, 1920	Sept. 27	9.68	1.52	11.20	.595				
	Aug. 25, 1921	...do...	9.02	3.55	12.57	.480				
	Sept. 18, 1922	Dec. 11	8.22	2.54	10.76	.598	.0949	.0422	.0527	13.47
	Sept. 27, 1923	Oct. 5	7.18	3.76	10.94	.410	.0746	.0241	.0505	12.75
	Oct. 1, 1925	Oct. 20	6.94	2.95	9.89	.168	.0878	.0377	.0501	11.74
Keeper	Sept. 24, 1921	Nov. 3	8.09	3.64	11.73	.650				
	Oct. 26, 1922	Oct. 27	8.52	3.00	11.52	.545	.0584	.0151	.0433	13.20
	Nov. 8, 1923	Nov. 16	7.72	3.24	10.96	.383	.0497	.0157	.0342	12.02
	Nov. 4, 1924	Nov. 18	8.44	.98	9.42	.392	.0448	.0135	.0313	
	Oct. 10, 1925	Nov. 2	7.42	2.62	10.04	.380	.0495	.0095	.0400	12.07
Klickatat	Sept. 13, 1921	Oct. 20	8.68	4.04	12.72	.507				
	Oct. 15, 1922	Oct. 21	7.32	2.93	10.25	.393	.0770	.0345	.0425	11.80
	Oct. 4, 1923	Nov. 22	8.43	2.91	11.34	.362	.0924	.0471	.0453	13.04
	Nov. 3, 1924	Nov. 4	6.86	3.06	9.92	.401	.0820	.0373	.0447	
	Oct. 3, 1925	Oct. 26	7.08	2.13	9.21	.260	.0750	.0325	.0425	
Kooroochiang	Oct. 30, 1920	Nov. 6	7.13	1.81	8.94	.976				11.58
	Oct. 13, 1922	Oct. 17	5.93	2.84	8.77	.850	.0614	.0202	.0412	
	Oct. 12, 1923	Oct. 19	6.10	4.35	10.45	.892	.0857	.0312	.0545	13.41
	Nov. 4, 1924	Dec. 1	6.06	3.36	9.42	.820	.0995	.0297	.0698	
	Oct. 10, 1925	Nov. 21	8.28	3.72	12.00	.567	.1035	.0400	.0635	13.61
Lawver	Oct. 12, 1920	Oct. 30	6.26	1.46	7.72	.617				
	Sept. 2, 1921	Oct. 21	8.20	3.43	11.63	.565				
	Sept. 29, 1922	Dec. 13	7.77	2.37	10.14	.563	.0729	.0342	.0387	
	Sept. 27, 1923	Sept. 29	7.43	3.77	11.20	.694	.0940	.0248	.0692	12.15
	Sept. 15, 1924	Oct. 9	7.74	2.32	10.06	.500	.1260	.0582	.0678	
Martha	Aug. 4, 1920	Sept. 1	8.95	1.85	10.80	.983				12.86
	July 30, 1921	Aug. 16	8.44	3.04	11.48	.904				
	July 28, 1922	July 29	7.37	2.47	9.84	.936	.1931	.0869	.1062	11.08
	Aug. 14, 1923	Aug. 27	9.36	2.33	11.69	.850	.2320	.1293	.1027	14.41
	Aug. 6, 1925	Aug. 10	8.76	2.92	11.68	.824	.1940	.0925	.1015	
Martin	Aug. 24, 1921	Oct. 23	9.00	3.57	12.57	.415				
	Sept. 30, 1922	Oct. 4	8.45	3.01	11.46	.291	.0851	.0347	.0504	13.43
	Oct. 20, 1923	Oct. 30	9.54	4.44	13.98	.228	.0881	.0385	.0496	15.53
	Oct. 11, 1924	Oct. 20	9.00	2.38	11.38	.252	.0704	.0218	.0486	
	Oct. 7, 1925	Oct. 29	10.82	2.44	13.26	.241	.1280	.0530	.0750	16.23
McAfee	Oct. 8, 1921	Oct. 26	7.86	3.05	10.91	.620				
	Oct. 3, 1922	Oct. 11	7.49	2.60	10.09	.507	.1078	.0499	.0579	13.01
	Oct. 13, 1923	Oct. 26	9.34	2.66	12.00	.394	.1035	.0428	.0607	13.60
	Oct. 21, 1924	Nov. 13	8.24	1.34	9.58	.375	.1132	.0422	.0710	
	Oct. 15, 1925	Nov. 16	8.56	1.68	10.24	.235	.1210	.0480	.0730	11.95

TABLE 1.—*Analytical results for the juices of 216 varieties of apples analyzed in three to six of the years 1920–1925*—Continued

Variety	Date picked	Date of analysis	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar after inversion	Acid as malic	Total astringency	Tannin	Non-tannin astringency	Total solids
Fruiting 5 years—Continued.										
McIntosh	Sept. 1, 1920	Sept. 16	8.13	1.66	9.79	0.423				
	Sept. 1, 1922	Sept. 5	8.03	1.39	9.42	.566	0.0966	0.0518	0.0448	11.36
	Sept. 5, 1923	Sept. 13	8.00	3.34	11.34	.646	.1248	.0616	.0632	13.44
	Sept. 13, 1924	Sept. 25	7.04	3.36	10.40	.419	.0717	.0294	.0423	
	Aug. 21, 1925	Sept. 8*	6.66	2.75	9.41	.371	.1040	.0398	.0642	11.84
Monmouth	Oct. 7, 1920	Oct. 30	7.74	2.02	9.76	.602				11.85
	Sept. 18, 1922	Sept. 23	7.60	1.99	9.59	.543	.0677	.0286	.0391	12.68
	Oct. 20, 1923	Nov. 6	7.74	3.03	10.77	.386	.0857	.0300	.0557	13.24
	Oct. 21, 1924	---do----	7.06	.96	8.02	.413	.0955	.0287	.0668	
	Oct. 5, 1925	Nov. 16	9.32	1.75	11.07	.300	.0985	.0403	.0582	12.91
Mother	Sept. 1, 1920	Sept. 19	9.46	.57	10.03	.413				
	Aug. 30, 1922	Sept. 15	6.89	4.15	11.04	.347	.1034	.0313	.0721	13.21
	Sept. 8, 1923	Sept. 22	6.86	4.48	11.34	.422	.1095	.0420	.0675	12.50
	Aug. 29, 1924	Sept. 15	6.97	4.37	11.34	.487	.1215	.0717	.0498	
	Sept. 14, 1925	Sept. 22	8.24	4.02	12.26	.267	.1242	.0742	.0500	14.08
Peron	Aug. 6, 1921	Sept. 16	7.11	3.05	10.16	.668				
	Aug. 16, 1922	Aug. 18	6.36	4.42	10.78	1.055	.1921	.1022	.0899	12.49
	Aug. 23, 1923	Sept. 5	6.12	4.12	10.24	.580	.1212	.0631	.0581	11.59
	Sept. 5, 1924	Sept. 16	5.16	3.32	8.48	.458	.1260	.0860	.0400	
	Sept. 1, 1925	Sept. 8	5.56	4.06	9.62	.313	.1415	.0663	.0752	12.43
Pifer	Sept. 13, 1920	Oct. 6	6.70	1.17	7.87	.449				11.01
	Oct. 11, 1921	Oct. 25	7.68	3.70	11.38	.354				
	Oct. 19, 1922	Oct. 20	8.26	1.90	10.16	.317	.0858	.0318	.0540	12.49
	Oct. 20, 1923	Oct. 26	10.02	4.03	14.05	.447	.1112	.0502	.0610	16.26
	Nov. 4, 1924	Nov. 29	9.36	2.00	11.36	.289	.0995	.0405	.0590	
Pyrus angustifolia.*	Oct. 11, 1921	Nov. 6	3.61	1.14	4.75	2.190	.5380	.3100	.2280	9.86
	Oct. 4, 1922	Oct. 4	2.98	.24	3.22	2.316	.6882	.3580	.3302	7.77
	Oct. 26, 1923	Nov. 23	3.94	1.61	5.55	2.004	.9350	.4960	.4390	10.40
	Nov. 1, 1924	Nov. 1	2.97	1.47	4.44	2.504	.6900	.3270	.3630	7.63
	Nov. 6, 1925	Nov. 21	2.94	1.40	4.34	2.140	.8350	.2930	.5420	8.13
Ralls	Sept. 2, 1921	Oct. 15	7.39	4.98	12.37	.680				
	Oct. 7, 1922	Oct. 12	7.81	3.07	10.88	.583	.0789	.0246	.0543	14.92
	Oct. 20, 1923	Oct. 26	8.32	3.37	11.69	.420	.0727	.0282	.0445	13.13
	Oct. 14, 1924	Oct. 23	7.62	2.89	10.51	.355	.0640	.0211	.0429	
	Oct. 10, 1925	Nov. 18	8.76	2.52	11.28	.286	.0950	.0368	.0582	13.31
Shackleford	Aug. 5, 1921	Sept. 15	6.16	3.76	9.92	.552				
	Sept. 6, 1922	Sept. 19	7.30	2.38	9.68	.535	.0695	.0261	.0434	11.64
	Sept. 27, 1923	Oct. 10	7.50	4.13	11.63	.480	.0945	.0335	.0610	14.61
	Oct. 14, 1924	Oct. 16	7.00	2.14	9.14	.423	.0977	.0394	.0583	
	Sept. 25, 1925	Oct. 13	7.48	3.45	10.93	.260	.1087	.0487	.0600	12.75
Shone	Sept. 2, 1921	Sept. 15	7.29	4.11	11.40	.645				
	Sept. 23, 1922	Dec. 7	8.81	2.62	11.43	.500	.0478	.0319	.0159	12.98
	Oct. 26, 1923	Nov. 2	8.00	4.24	12.24	.576	.0700	.0297	.0403	13.62
	Oct. 11, 1924	Oct. 22	7.10	3.20	10.30	.467	.0662	.0165	.0497	
	Oct. 3, 1925	Oct. 31	8.78	2.72	11.50	.374	.0638	.0188	.0450	13.77
Smokehouse	Sept. 3, 1921	Sept. 26	9.07	3.81	12.88	.672				
	Sept. 28, 1922	Oct. 13	6.77	4.12	10.89	.553	.0747	.0204	.0543	12.09
	Oct. 4, 1923	Nov. 14	9.02	4.06	13.08	.559	.1200	.0472	.0728	15.70
	Sept. 13, 1924	Oct. 8	7.00	1.80	8.80	.440	.1020	.0412	.0608	11.20
	Oct. 3, 1925	Oct. 22	9.60	2.35	11.95	.378	.1225	.0457	.0768	15.12
Soulard	Nov. 1, 1920	Nov. 18	7.34	2.14	9.48	.807				12.15
	Oct. 11, 1921	Nov. 2	6.02	2.12	8.14	.861				
	Oct. 16, 1922	Oct. 18	5.90	1.39	7.29	.761	.1980	.1305	.0675	11.00
	Oct. 4, 1923	Dec. 6	5.28	1.71	6.99	.616	.2860	.1835	.1025	10.16
	Nov. 3, 1925	Nov. 25	6.18	2.36	8.54	.633	.3420	.1965	.1455	11.15
Sutton	Oct. 15, 1920	Nov. 11	6.72	3.20	9.92	.386				
	Sept. 23, 1922	Nov. 3	7.36	2.78	10.14	.456	.1071	.0354	.0717	12.71
	Sept. 23, 1923	Oct. 5	7.58	4.92	12.50	.615	.0815	.0267	.0548	13.37
	Sept. 24, 1924	Oct. 8	11.94	1.76	13.70	.585	.0960	.0368	.0592	
	Oct. 1, 1925	Oct. 6	7.18	5.38	12.56	.384	.1170	.0470	.0700	15.52

See footnote at end of table.

TABLE 1.—*Analytical results for the juices of 216 varieties of apples analyzed in three to six of the years 1920–1925*—Continued

Variety	Date picked	Date of analysis	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar after inversion	Acid as malic	Total astringency	Tannin	Non-tannin astringency	Total solids
Fruiting 5 years—Continued.										
Swaar	Oct. 8, 1920	Oct. 30	10.13	3.77	13.90	0.612				14.66
	Sept. 23, 1922	Oct. 31	8.07	3.71	11.78	.598	0.1115	0.0398	0.0717	14.97
	Sept. 28, 1923	Oct. 8	8.14	4.64	12.78	.587	.0832	.0276	.0556	15.12
	Oct. 11, 1924	Oct. 22	9.03	3.64	12.67	.762	.1280	.0525	.0755	
	Oct. 1, 1925	Oct. 23	8.06	4.42	12.48	.437	.0705	.0135	.0570	14.92
Sweet Orange	Sept. 24, 1921	Oct. 17	8.92	3.80	12.72	.404				
	Oct. 25, 1922	Oct. 30	7.33	6.54	13.87	.152	.0973	.0318	.0655	
	Oct. 12, 1923	Oct. 26	10.63	3.21	13.84	.420	.0935	.0403	.0532	14.79
	Nov. 4, 1924	Nov. 11	10.48	2.64	13.12	.136	.0702	.0271	.0431	
	Oct. 13, 1925	Nov. 2	10.16	3.65	13.81	.166	.1110	.0370	.0740	16.33
Titus	Oct. 8, 1920	Oct. 24	8.06	1.89	9.95	.535				
	Aug. 25, 1921	Oct. 30	8.30	3.10	11.40	.407				13.98
	Sept. 23, 1922	Nov. 13	7.52	2.80	10.32	.279	.1717	.0933	.0784	
	Sept. 28, 1923	Oct. 2	7.32	2.87	10.19	.582	.1182	.0557	.0625	13.14
	Oct. 1, 1925	Oct. 26	9.32	1.92	11.24	.314	.1390	.0630	.0760	14.74
Tompkins King	Sept. 16, 1920	Oct. 16	7.94	2.06	10.00	.537				
	Sept. 23, 1922	Dec. 11	8.71	1.74	10.45	.542	.0984	.0501	.0483	13.07
	Sept. 28, 1923	Oct. 8	9.48	3.25	12.73	.410	.1123	.0428	.0695	15.93
	Sept. 24, 1924	Oct. 3	7.23	2.75	9.98	.423	.1030	.0342	.0688	
	Sept. 15, 1925	Oct. 19	7.26	4.07	11.33	.350	.1075	.0407	.0668	13.65
Transcendent	Aug. 6, 1920	Aug. 24	7.96	2.42	10.38	.912				
	Aug. 1, 1922	Aug. 7	8.32	1.66	9.98	1.140	.3617	.1696	.1921	11.84
	Aug. 20, 1923	Aug. 27	7.44	4.27	11.71	.783	.2530	.1415	.1115	14.44
	Aug. 18, 1924	Aug. 21	7.64	1.16	8.80	.417	.3180	.1230	.1950	
	Aug. 8, 1925	Aug. 10	6.41	3.68	10.09	.776	.2136	.1026	.1110	
Vanderpool	Aug. 31, 1921	Oct. 1	7.43	4.65	12.08	.503				
	Sept. 28, 1922	Dec. 12	8.96	4.14	13.10	.391	.0862	.0393	.0469	15.67
	Sept. 16, 1923	Oct. 1	8.24	4.64	12.88	.535	.1476	.0711	.0765	15.71
	Oct. 4, 1924	Oct. 21	10.70	4.26	14.96	.397	.1295	.0525	.0770	
	Sept. 16, 1925	Oct. 29	9.84	2.33	12.17	.260	.1280	.0600	.0680	14.47
Vandevere	Oct. 6, 1921	Oct. 24	9.86	2.06	11.92	.480				
	Sept. 25, 1922	Oct. 13	6.78	4.11	10.89	.553	.0745	.0202	.0543	12.07
	Oct. 12, 1923	Oct. 23	9.12	5.41	14.53	.612	.1321	.0455	.0866	16.96
	Oct. 8, 1924	Oct. 20	7.96	4.30	12.26	.560	.1080	.0515	.0565	
	Sept. 17, 1925	Nov. 16	7.12	3.31	10.43	.308	.0703	.0215	.0488	12.06
Westfield	Sept. 6, 1920	Oct. 17	9.22	2.30	11.52	.482				
	Oct. 3, 1922	Oct. 7	7.33	3.03	10.36	.456	.1113	.0561	.0552	12.96
	Oct. 26, 1923	Nov. 2	8.00	5.87	13.87	.525	.1157	.0429	.0728	15.42
	Oct. 14, 1924	Oct. 17	7.86	2.34	10.20	.437	.0840	.0230	.0610	
	Oct. 7, 1925	Oct. 16	7.24	4.94	12.18	.415	.1200	.0390	.0810	14.95
White Doctor	Sept. 3, 1920	Oct. 16	7.50	2.10	9.60	.590				
	Aug. 16, 1921	Oct. 7	7.33	2.35	9.68	.303				
	Aug. 24, 1922	Oct. 4	6.32	2.74	9.06	.672	.0982	.0400	.0582	11.54
	Sept. 27, 1923	Nov. 21	8.41	2.98	11.39	.507	.0852	.0262	.0590	15.04
	Sept. 13, 1924	Sept. 26	5.82	2.66	8.48	.650	.0936	.0347	.0589	
White Pippin	Oct. 9, 1920	Oct. 20	8.68	1.01	9.69	.630				11.12
	Sept. 11, 1921	Oct. 13	8.40	3.08	11.48	.651				
	Oct. 13, 1922	Oct. 19	6.34	4.70	11.04	.522	.0717	.0275	.0442	
	Sept. 28, 1923	Nov. 14	6.62	4.77	11.39	.470	.0995	.0430	.0565	13.42
	Oct. 4, 1924	Oct. 9	6.04	4.02	10.06	.595	.0950	.0308	.0642	
Wolf River	Sept. 1, 1920	Oct. 2	7.39	1.38	8.77	.520				
	Aug. 19, 1922	Aug. 25	5.68	1.96	7.64	.786	.0766	.0235	.0531	10.18
	Sept. 27, 1923	Sept. 29	7.87	1.81	9.68	.740	.0940	.0352	.0588	13.22
	Sept. 15, 1924	Sept. 20	5.76	1.86	7.62	.559	.0765	.0342	.0423	
	Sept. 16, 1925	Sept. 23	5.70	3.01	8.71	.560	.0750	.0333	.0417	11.17
Yellow Bellflower	Oct. 13, 1920	Nov. 2	7.86	2.16	10.02	.636				13.82
	Sept. 2, 1921	Nov. 6	9.00	3.77	12.77	.595				
	Oct. 3, 1922	Oct. 5	7.36	3.17	10.53	.571	.0885	.0324	.0561	
	Oct. 26, 1923	Oct. 31	9.40	5.56	14.96	.635	.1346	.0465	.0881	16.02
	Sept. 16, 1925	Oct. 6	6.76	3.43	10.19	.424	.0953	.0343	.0610	

TABLE 1.—*Analytical results for the juices of 216 varieties of apples analyzed in three to six of the years 1920–1925*—Continued

Variety	Date picked	Date of analysis	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar after inversion	Acid as malic	Total astringency	Tannin	Non-tannin astringency	Total solids
Fruiting 4 years:										
Abernathy	Aug. 23, 1922	Aug. 28	8.70	0.44	9.14	0.421	0.0940	0.0250	0.0690	11.85
	Aug. 29, 1923	Dec. 12	8.90	2.04	10.94	.395	.1652	.0860	.0792	12.49
	Sept. 15, 1924	Sept. 25	7.18	2.66	9.84	.339	.0813	.0358	.0455	------
	Aug. 30, 1925	Sept. 14	7.84	2.32	10.16	.294	.1150	.0516	.0634	12.48
Algérienne	Aug. 19, 1922	Aug. 28	5.93	4.07	10.00	.383	.2761	.1104	.1657	13.60
	Sept. 13, 1923	Sept. 21	5.97	5.58	11.55	.221	.2500	.1315	.1185	12.97
	Aug. 16, 1924	Aug. 24	5.02	4.24	9.26	.231	.1930	.1008	.0922	------
	Oct. 7, 1925	Oct. 13	8.28	3.66	11.94	.150	.1570	.0812	.0758	14.29
Allington Pippin[b]	Aug. 29, 1922	Sept. 13	8.47	3.14	11.61	.946	.1206	.0460	.0746	12.66
	Sept. 24, 1923	Oct. 1	8.42	2.15	10.57	.585	.1290	.0580	.0710	12.53
	Sept. 13, 1924	Sept. 27	6.84	1.50	8.34	.615	.0892	.0446	.0446	------
	Sept. 15, 1925	Nov. 7	6.65	2.55	9.20	.338	.1065	.0507	.0558	11.07
Amère du Surville.	Sept. 23, 1922	Dec. 14	8.98	.94	9.92	.410	.3384	.2136	.1248	13.91
	Sept. 4, 1923	Sept. 19	9.70	1.64	11.34	.248	.7400	.4220	.3180	13.21
	Oct. 18, 1924	Nov. 8	8.97	2.01	10.98	.148	.4360	.2795	.1565	------
	Oct. 10, 1925	Oct. 17	11.06	1.82	12.88	.176	.4740	.2140	.2600	15.87
Arctic	Sept. 28, 1922	Dec. 8	8.26	2.15	10.41	.439	.1155	.0358	.0797	------
	Sept. 16, 1923	Nov. 15	9.13	4.84	13.97	.608	.1648	.0622	.1026	16.76
	Sept. 21, 1924	Oct. 2	6.72	3.38	10.10	.525	.1660	.0760	.0900	------
	Sept. 10, 1925	Sept. 26	8.62	1.84	10.46	.360	.1265	.0518	.0747	13.33
Arnold	Aug. 30, 1921	Sept. 16	9.27	2.36	11.63	.776	------	------	------	------
	Sept. 1, 1922	Sept. 5	9.30	2.70	12.00	.583	.0949	.0181	.0768	14.03
	Sept. 16, 1923	Sept. 26	7.44	4.08	11.52	.617	.0938	.0394	.0544	12.89
	Sept. 13, 1924	Sept. 24	7.98	2.60	10.58	.480	.0990	.0549	.0441	------
Babbitt	Aug. 29, 1922	Sept. 14	7.04	2.96	10.00	1.182	.1095	.0348	.0747	12.70
	Sept. 27, 1923	Sept. 29	7.44	3.26	10.70	1.130	.0957	.0317	.0640	12.98
	Sept. 13, 1924	Oct. 8	7.64	2.92	10.56	1.112	.1185	.0370	.0815	------
	Sept. 17, 1925	Oct. 7	8.44	2.01	10.45	.910	.1002	.0337	.0665	13.54
Ben Hur	Oct. 6, 1922	Oct. 10	7.12	3.21	10.33	.368	.0763	.0211	.0552	12.94
	Oct. 9, 1923	Oct. 16	7.88	3.72	11.60	.373	.0778	.0281	.0497	14.16
	Nov. 4, 1924	Nov. 11	8.36	2.98	11.34	.312	.0650	.0228	.0422	------
	Oct. 10, 1925	Nov. 2	7.35	2.99	10.34	.196	.0832	.0357	.0475	12.49
Bennet	Oct. 7, 1922	Oct. 17	7.24	5.64	12.88	.444	.0894	.0298	.0596	14.34
	Oct. 12, 1923	Oct. 20	8.16	4.90	13.06	.385	.0915	.0298	.0617	14.04
	Oct. 4, 1924	Dec. 3	6.92	2.18	9.10	.235	.0810	.0464	.0346	------
	Oct. 8, 1925	Nov. 7	7.80	2.42	10.22	.312	.0977	.0423	.0554	12.01
Bethlehemite	Aug. 19, 1922	Sept. 19	10.13	2.40	12.53	.350	.0799	.0365	.0434	14.53
	Sept. 27, 1923	Oct. 9	9.54	2.30	11.84	.385	.0945	.0379	.0566	14.53
	Sept. 24, 1924	Oct. 8	8.72	2.32	11.04	.349	.1015	.0440	.0575	------
	Oct. 1, 1925	Oct. 13	8.58	1.34	9.92	.150	.0952	.0451	.0501	11.88
Black Annette	Oct. 15, 1921	Oct. 30	8.67	4.27	12.94	.555	------	------	------	------
	Oct. 20, 1922	Oct. 25	6.54	3.94	10.48	.418	.1000	.0280	.0720	13.32
	Oct. 20, 1923	Oct. 27	7.48	5.82	13.30	.615	.1035	.0358	.0677	15.97
	Nov. 4, 1924	Dec. 2	6.82	3.24	10.06	.366	.1072	.0312	.0760	------
Boiken	Sept. 14, 1920	Sept. 27	6.86	2.10	8.96	.830	------	------	------	------
	Sept. 23, 1922	Oct. 19	6.50	3.98	10.48	.811	.0672	.0274	.0398	11.08
	Sept. 19, 1923	Nov. 30	7.04	3.23	10.27	.589	.0762	.0335	.0427	11.96
	Oct. 8, 1924	Oct. 20	7.00	2.43	9.43	.784	.0635	.0301	.0334	------
Camak	Sept. 23, 1921	Oct. 23	8.16	2.56	10.72	.396	------	------	------	------
	Sept. 30, 1922	Oct. 3	6.50	4.26	10.76	.423	.0843	.0261	.0582	13.20
	Oct. 20, 1923	Oct. 29	7.26	3.76	11.02	.272	.0917	.0489	.0428	11.94
	Sept. 25, 1925	Oct. 19	7.26	2.17	9.43	.227	.1000	.0432	.0568	11.81
Canada Reinette	Sept. 22, 1921	Oct. 26	8.20	1.99	10.19	.430	------	------	------	11.68
	Sept. 23, 1922	Dec. 5	8.80	2.94	11.74	.634	.1219	.0701	.0518	15.50
	Sept. 27, 1923	Oct. 4	7.38	4.79	12.17	1.010	.1270	.0445	.0825	16.69
	Sept. 15, 1924	Oct. 6	7.10	3.08	10.18	.710	.1515	.0805	.0710	------

See footnote at end of table.

TABLE 1.—*Analytical results for the juices of 216 varieties of apples analyzed in three to six of the years 1920–1925*—Continued

Variety	Date picked	Date of analysis	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar after inversion	Acid as malic	Total astringency	Tannin	Non-tannin astringency	Total solids
Fruiting 4 years—Continued.										
Carson	Sept. 6, 1922	Nov. 6	6.98	2.72	9.70	0.583	0.1239	0.0460	0.0779	11.76
	Sept. 19, 1923	Sept. 26	6.26	3.21	9.47	.595	.0658	.0080	.0578	11.72
	Sept. 7, 1924	Sept. 22	5.24	3.86	9.10	.752	.0540	.0165	.0375	------
	Sept. 16, 1925	Sept. 25	8.10	2.67	10.77	.530	.0610	.0186	.0424	13.01
Catline	Aug. 24, 1921	Sept. 20	7.12	2.68	9.80	.577	------	------	------	------
	Sept. 6, 1922	Oct. 17	7.14	3.44	10.58	.507	.1157	.0789	.0368	13.49
	Sept. 16, 1923	Oct. 2	8.14	3.86	12.00	.495	.1010	.0385	.0625	14.27
	Oct. 1, 1925	Oct. 17	7.94	2.65	10.59	.372	.1125	.0482	.0643	13.54
Clayton	Oct. 14, 1920	Nov. 3	9.12	3.45	12.57	.458	------	------	------	13.86
	Sept. 23, 1922	Nov. 15	9.79	2.67	12.46	.349	.1103	.0420	.0683	------
	Sept. 13, 1923	Sept. 28	9.14	3.52	12.66	.773	.1070	.0360	.0710	15.64
	Oct. 11, 1924	Oct. 22	8.19	2.77	10.96	.370	.1140	.0508	.0632	------
Cox No. 12	Aug. 21, 1921	Sept. 13	7.38	3.15	10.53	.353	------	------	------	------
	Sept. 18, 1922	Sept. 21	7.00	3.96	10.96	.391	.0695	.0070	.0625	13.38
	Sept. 19, 1923	Sept. 24	7.44	2.67	10.11	.293	.0870	.0316	.0554	12.91
	Sept. 16, 1925	Oct. 5	7.38	1.64	9.02	.156	.0920	.0395	.0525	10.90
Cox No. 13	Sept. 18, 1922	Dec. 7	9.20	1.82	11.02	.508	.0504	.0163	.0341	14.69
	Sept. 19, 1923	Sept. 26	7.22	3.64	10.86	.530	.0640	.0150	.0490	12.37
	Oct. 21, 1924	Oct. 23	7.03	2.78	9.81	.376	.0590	.0170	.0420	11.64
	Sept. 16, 1925	Oct. 5	7.36	1.72	9.08	.269	.0584	.0190	.0394	11.03
Delicious	Sept. 25, 1920	Oct. 6	9.55	1.05	10.60	.254	------	------	------	------
	Sept. 21, 1921	Oct. 18	7.39	4.30	11.69	.313	------	------	------	------
	Oct. 7, 1922	Oct. 11	7.28	2.82	10.10	.279	.0868	.0377	.0491	12.46
	Oct. 14, 1924	Nov. 4	8.24	1.98	10.22	.216	.0760	.0322	.0438	------
Dickey	Oct. 1, 1920	Oct. 27	7.66	2.09	9.75	.610	------	------	------	12.93
	Oct. 20, 1923	Oct. 30	8.74	4.49	13.23	.412	.0908	.0291	.0617	14.97
	Oct. 11, 1924	Oct. 21	7.68	3.34	11.02	.390	.0910	.0430	.0480	------
	Oct. 1, 1925	Oct. 20	7.86	3.23	11.09	.346	.1042	.0384	.0658	14.56
Dixon	Sept. 23, 1922	Nov. 8	8.20	2.49	10.69	.368	.0876	.0460	.0416	13.76
	Oct. 8, 1923	Oct. 13	7.66	1.82	9.48	.582	.0703	.0163	.0540	12.35
	Oct. 8, 1924	Oct. 22	8.36	3.12	11.48	.615	.0590	.0100	.0490	------
	Sept. 23, 1925	Oct. 26	7.10	1.79	8.89	.372	.0620	.0186	.0434	------
Domine	Oct. 7, 1922	Oct. 11	6.78	3.15	9.93	.426	.0947	.0711	.0236	12.83
	Oct. 8, 1923	Nov. 19	8.55	4.43	12.98	.514	.1110	.0606	.0504	12.10
	Oct. 11, 1924	Oct. 21	7.13	2.71	9.84	.443	.0635	.0267	.0368	------
	Sept. 17, 1925	Oct. 8	8.70	3.19	11.89	.372	.0920	.0378	.0542	14.84
Dudley	Aug. 17, 1920	Sept. 2	8.40	1.78	10.18	.752	------	------	------	------
	July 23, 1922	July 28	6.21	3.15	9.36	1.093	.1369	.0245	.1124	11.98
	Aug. 4, 1923	Aug. 13	5.90	2.30	8.20	.762	.1223	.0478	.0745	10.58
	Sept. 5, 1924	Sept. 12	5.08	2.58	7.66	.545	.0791	.0351	.0440	------
Dulaney	Sept. 13, 1921	Sept. 26	9.03	2.33	11.36	.531	------	------	------	------
	Oct. 13, 1922	Oct. 16	9.10	1.67	10.77	.355	.0894	.0429	.0465	12.94
	Oct. 20, 1923	Oct. 29	9.95	2.55	12.50	.408	.0925	.0368	.0557	14.02
	Oct. 10, 1925	Nov. 18	8.66	1.45	10.11	.215	.1175	.0540	.0635	12.71
Early Cooper	July 19, 1921	Aug. 8	6.16	2.51	8.67	.586	------	------	------	------
	July 3, 1923	Aug. 6	7.06	.92	7.98	.570	.1110	.0512	.0598	9.19
	Aug. 18, 1924	Aug. 27	8.32	.94	9.26	.525	.0834	.0563	.0271	------
	Aug. 4, 1925	Aug. 12	7.96	1.62	9.58	.404	.1108	.0551	.0557	------
Early Ripe	July 14, 1920	July 17	6.32	1.06	7.38	.887	------	------	------	------
	July 10, 1922	July 10	5.76	1.52	7.28	.691	.1216	.0552	.0664	10.64
	July 13, 1923	July 23	7.54	2.60	10.14	.921	.1085	.0700	.0385	------
	July 24, 1924	Aug. 4	6.00	.16	6.16	.683	.0895	.0308	.0587	------
Fallawater	Sept. 18, 1920	Oct. 20	9.63	1.14	10.77	.374	------	------	------	12.16
	Sept. 18, 1922	Oct. 31	9.26	------	9.26	.221	.1124	.0355	.0769	12.23
	Sept. 27, 1923	Oct. 4	8.61	3.42	12.03	.418	.0780	.0162	.0618	15.42
	Oct. 8, 1924	Oct. 11	7.53	2.24	9.77	.256	.0832	.0316	.0516	------

TABLE 1.—*Analytical results for the juices of 216 varieties of apples analyzed in three to six of the years 1920–1925*—Continued

Variety	Date picked	Date of analysis	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar after inversion	Acid as malic	Total astringency	Tannin	Non-tannin astringency	Total solids
Fruiting 4 years—Continued.										
Fameuse	Sept. 12, 1920	Sept. 27	10.00	1.26	11.26	0.420				12.71
	Sept. 27, 1923	Oct. 4	8.98	3.05	12.03	.580	0.0960	0.0308	0.0652	15.45
	Sept. 15, 1924	Sept. 25	7.12	2.32	9.44	.454	.0900	.0362	.0538	
	Sept. 15, 1925	Sept. 23	8.80	2.48	11.28	.325	.0996	.0454	.0542	13.95
Florence	Aug. 23, 1921	Aug. 30	7.96	.36	8.32	1.105				
	July 24, 1922	July 28	6.29	1.19	7.48	.836	.3229	.1441	.1788	9.30
	Aug. 9, 1924	Aug. 27	7.06	.59	7.65	.639	.2900	.1404	.1496	
	July 29, 1925	Aug. 18	8.52	.60	9.12	.620	.1940	.0942	.0998	
Flory	Aug. 19, 1922	Aug. 28	5.35	3.42	8.77	.847	.1044	.0181	.0863	11.38
	Sept. 21, 1923	Sept. 26	5.58	3.30	8.88	.654	.0850	.0315	.0535	11.07
	Sept. 13, 1924	...do....	4.78	2.84	7.62	.497	.1140	.0535	.0605	
	Sept. 9, 1925	Sept. 14	6.16	2.46	8.62	.505	.0808	.0192	.0616	11.02
Gold Medal	Oct. 8, 1920	Oct. 19	9.12	2.24	11.36	.520				12.97
	Oct. 7, 1922	...do....	8.51	1.89	10.40	.241	.0885	.0460	.0425	11.63
	Oct. 8, 1924	Oct. 16	9.01	2.65	11.66	.318	.1090	.0595	.0495	
	Oct. 16, 1925	Nov. 23	9.32	3.24	12.56	.163	.1120	.0580	.0540	13.46
Golden Russet	Oct. 8, 1920	Oct. 26	10.28	.39	10.67	.478	.0900	.0332	.0568	12.39
	Sept. 23, 1922	Nov. 17	11.01	1.33	12.34	.476	.0800	.0223	.0637	
	Sept. 28, 1923	Oct. 5	9.43	3.55	12.98	.605	.0961	.0386	.0575	15.46
	Oct. 8, 1924	Oct. 21	9.00	2.82	11.82	.447	.0800	.0303	.0497	
Greenville	Sept. 28, 1922	Nov. 3	6.62	3.51	10.13	.438	.1097	.0478	.0619	12.89
	Sept. 15, 1923	Sept. 29	6.66	4.27	10.93	.675	.0825	.0370	.0455	12.20
	Sept. 24, 1924	Oct. 4	5.38	4.74	10.12	.667	.0942	.0445	.0497	
	Oct. 1, 1925	Oct. 16	6.92	3.59	10.51	.422	.1045	.0460	.0585	13.10
Haas	Aug. 19, 1922	Aug. 21	8.71	2.67	11.38	1.050	.1191	.0255	.0936	13.26
	Sept. 16, 1923	Dec. 6	7.26	2.15	9.41	.445	.0852	.0272	.0580	14.30
	Sept. 5, 1924	Sept. 19	7.05	1.57	8.62	.583	.1170	.0410	.0760	
	Sept. 14, 1925	Sept. 22	7.72	3.11	10.83	.477	.1320	.0500	.0820	13.84
Hagloe Crab	July 26, 1922	July 28	6.23	1.26	7.49	1.104	.1359	.0123	.1236	9.86
	Sept. 3, 1923	Sept. 11	6.49	1.81	8.30	.484	.0930	.0430	.0500	8.86
	Sept. 5, 1924	Sept. 12	6.24	.84	7.08	.494	.1025	.0495	.0530	
	Aug. 21, 1925	Sept. 3	5.58	2.08	7.66	.449	.0965	.0425	.0540	10.94
Hoover	Sept. 1, 1922	Sept. 19	8.02	1.57	9.59	.604	.0808	.0243	.0565	11.28
	Sept. 8, 1923	Oct. 2	9.02	1.75	10.77	.676	.0942	.0368	.0574	13.29
	Sept. 13, 1924	Sept. 27	6.69	2.25	8.94	.561	.1245	.0641	.0604	
	Sept. 25, 1925	Oct. 19	8.84	1.51	10.35	.417	.0901	.0291	.0610	12.69
Huntsman	Oct. 13, 1922	Nov. 3	6.57	4.13	10.70	.279	.0982	.0292	.0690	11.84
	Sept. 28, 1923	Oct. 8	7.18	5.14	12.32	.476	.0763	.0216	.0547	13.97
	Oct. 8, 1924	Oct. 15	6.98	3.90	10.88	.502	.0832	.0154	.0678	
	Oct. 1, 1925	Oct. 26	6.66	2.48	9.14	.260	.0859	.0309	.0550	11.16
Hyslop	Aug. 29, 1922	Sept. 13	5.54	3.48	9.02	.583	.3284	.2077	.1207	11.62
	Sept. 8, 1923	Sept. 18	4.38	7.03	11.41	.517	.3180	.1768	.1412	12.79
	Sept. 13, 1924	Sept. 22	3.37	6.21	9.58	.567	.3700	.2390	.1310	
	Sept. 5, 1925	Sept. 14	3.44	5.92	9.36	.358	.2180	.1345	.0835	13.16
Hort. No. 3050 [c]	Oct. 11, 1921	Nov. 4	10.16	1.76	11.92	.454				
	Nov. 3, 1923	Nov. 6	8.79	2.92	11.71	.408	.1440	.0610	.0830	15.08
	Nov. 2, 1924	...do....	9.20	1.68	10.88	.437	.1320	.0565	.0755	
	Oct. 16, 1925	Oct. 31	9.68	1.76	11.44	.242	.1260	.0495	.0765	14.70
Hort. No. 4941 [d]	Oct. 25, 1922	Oct. 30	9.06	3.84	12.90	.182	.1486	.0531	.0955	15.51
	Oct. 12, 1923	Oct. 26	8.46	3.17	11.63	.260	.1122	.0437	.0685	13.87
	Nov. 4, 1924	Nov. 18	9.24	4.12	13.36	.156	.1235	.0500	.0735	
	Oct. 15, 1925	Nov. 24	7.86	4.25	12.11	.150	.1283	.0443	.0840	13.97
Ingram	Sept. 13, 1921	Sept. 26	8.20	3.16	11.36	.442				
	Sept. 23, 1922	Nov. 15	7.46	3.30	10.76	.412	.1208	.0551	.0657	13.46
	Oct. 8, 1923	Oct. 12	8.00	2.77	10.77	.443	.0727	.0265	.0462	12.49
	Oct. 7, 1925	Nov. 23	7.92	3.36	11.28	.332	.1205	.0495	.0710	13.31

See footnotes at end of table.

TABLE 1.—*Analytical results for the juices of 216 varieties of apples analyzed in three to six of the years 1920–1925*—Continued

Variety	Date picked	Date of analysis	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar after inversion	Acid as malic	Total astringency	Tannin	Non-tannin astringency	Total solids
Fruiting 4 years—Continued.										
Jersey Sweet	Aug. 17, 1921	Sept. 16	8.30	2.47	10.77	0.118				
	Aug. 3, 1922	Aug. 4	7.61	3.85	11.46	.190	0.1645	0.0603	0.1042	13.26
	July 29, 1923	Aug. 7	5.44	3.71	9.15	.104	.1210	.0552	.0658	11.31
	Aug. 29, 1924	Sept. 2	6.91	3.59	10.50	.082	.0872	.0184	.0688	
Kentucky Sweet	Aug. 23, 1922	Aug. 28	8.89	1.00	9.89	.269	.2002	.1243	.0759	13.59
	Aug. 27, 1923	Sept. 12	8.31	3.33	11.64	.179	.1960	.0960	.1000	12.63
	Sept. 13, 1924	Sept. 27	7.66	2.38	10.04	.154	.1275	.0555	.0720	
	Sept. 1, 1925	Sept. 3	6.74	2.14	8.88	.149	.1180	.0580	.0600	12.54
Kinnard	Sept. 6, 1921	Oct. 8	6.34	4.44	10.78	.481	.0803	.0253	.0640	
	Sept. 28, 1923	Nov. 5	7.82	3.94	11.76	.435	.1080	.0439	.0641	13.66
	Oct. 8, 1924	Oct. 22	6.64	3.38	10.02	.470	.1045	.0473	.0572	
	Oct. 15, 1925	Oct. 31	7.54	2.09	9.63	.314	.0899	.0302	.0597	12.19
Lou	July 24, 1920	Aug. 6	7.32	.32	7.64	.864	.0717	.0111	.0606	
	June 26, 1922	July 5	6.60	2.24	8.84	.979	.0940	.0184	.0756	9.74
	July 16, 1923	July 18	5.64	2.23	7.87	1.498	.0906	.0341	.0565	9.89
	July 23, 1924	Aug. 6	5.69	1.09	6.78	.636	.0895	.0365	.0530	
Lyman	Aug. 25, 1921	Aug. 30	9.48	1.18	10.66	.627	.2125	.1725	.0400	
	Aug. 19, 1922	Aug. 29	9.47	2.11	11.58	.685	.5229	.2105	.3124	15.88
	Sept. 13, 1924	Sept. 22	8.61	3.29	11.90	.511	.4340	.2260	.2080	
	Aug. 26, 1925	Sept. 3	9.98	2.48	12.46	.540	.5200	.2935	.2265	16.76
Magg	Sept. 25, 1922	Dec. 9	8.11	.91	9.02	.463	.0545	.0387	.0158	
	Oct. 4, 1923	Nov. 23	7.72	3.91	11.63	.520	.1275	.0635	.0640	12.60
	Oct. 4, 1924	Oct. 14	7.13	2.62	9.75	.647	.1390	.0549	.0841	
	Oct. 1, 1925	Oct. 13	8.03	1.65	9.68	.365	.0999	.0439	.0560	11.39
Magog	Sept. 28, 1922	Nov. 14	8.12	2.80	10.92	.426	.0858	.0168	.0690	13.11
	Sept. 23, 1923	Sept. 28	9.56	2.93	12.49	.663	.1115	.0360	.0755	14.80
	Sept. 27, 1924	Oct. 10	7.34	1.54	8.88	.627	.1870	.0865	.1005	
	Sept. 15, 1925	Sept. 25	8.02	1.00	9.02	.463	.0844	.0277	.0567	11.45
Mann	Oct. 13, 1922	Oct. 20	8.58	2.95	11.53	.558	.1088	.0495	.0593	13.71
	Oct. 20, 1923	Oct. 22	8.36	5.26	13.62	.690	.1112	.0477	.0635	16.31
	Nov. 4, 1924	Dec. 1	8.92	1.48	10.40	.580	.1090	.0169	.0921	
	Sept. 25, 1925	Nov. 16	10.44	2.98	13.42	.417	.1330	.0686	.0644	16.75
McMahon	Aug. 7, 1922	Aug. 8	6.92	.58	7.50	.963	.1349	.0287	.1062	10.07
	Aug. 15, 1923	Aug. 17	6.36	1.88	8.24	1.016	.0870	.0378	.0492	9.81
	Aug. 29, 1924	Sept. 3	6.35	1.35	7.70	.752	.0937	.0214	.0723	
	Aug. 1, 1925	Sept. 8	6.06	2.68	8.74	.508	.0876	.0328	.0548	10.94
Melon	Sept. 25, 1920	Oct. 6	8.98	1.45	10.43	.354	.1032	.0237	.0795	11.91
	Sept. 1, 1922	Sept. 14	7.25	3.23	10.48	.505	.1190	.0547	.0643	14.03
	Oct. 20, 1923	Oct. 26	7.70	1.74	9.44	.277	.0858	.0403	.0455	10.14
	Oct. 1, 1925	Oct. 12	9.14	1.10	10.24	.195	.1246	.0495	.0751	
Menagere	Sept. 30, 1922	Dec. 5	9.20	2.58	11.78	.463	.1084	.0622	.0462	14.51
	Oct. 4, 1923	Nov. 28	8.81	3.91	12.72	.398	.0981	.0459	.0522	15.34
	Oct. 4, 1924	Oct. 9	6.65	3.61	10.26	.397	.0745	.0282	.0463	
	Sept. 23, 1925	Nov. 3	6.38	1.43	7.81	.188	.0825	.0400	.0425	9.97
Missouri Pippin	Oct. 2, 1922	Oct. 5	7.60	1.70	9.30	.418	.1017	.0145	.0872	11.59
	Sept. 8, 1923	Oct. 18	6.62	4.15	10.77	.620	.0805	.0205	.0600	13.29
	Nov. 4, 1924	Nov. 25	6.97	4.93	11.90	.584	.0947	.0329	.0618	
	Oct. 5, 1925	Nov. 24	8.20	4.95	13.15	.490	.1390	.0490	.0900	16.83
Morris Red	Sept. 21, 1921	Oct. 18	10.02	2.44	12.46	.515	.0675	.0135	.0540	
	Oct. 3, 1922	Oct. 16	6.58	4.46	11.04	.279	.0763	.0132	.0631	15.30
	Sept. 8, 1923	...do	7.60	4.61	12.11	.457	.0960	.0428	.0532	15.74
	Oct. 8, 1924	Oct. 14	8.14	2.26	10.40	.247	.1167	.0542	.0625	
Nickajack	Oct. 10, 1922	Oct. 12	7.65	2.13	9.78	.451	.0877	.0316	.0561	13.81
	Oct. 12, 1923	Oct. 22	8.72	5.06	13.78	.330	.0935	.0361	.0574	15.99
	Nov. 4, 1924	Nov. 22	9.70	4.32	14.02	.377	.0915	.0342	.0573	
	Oct. 12, 1925	Nov. 23	10.30	1.46	11.76	.274	.1440	.0514	.0926	15.42

TABLE 1.—*Analytical results for the juices of 216 varieties of apples analyzed in three to six of the years 1920–1925*—Continued

Variety	Date picked	Date of analysis	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar after inversion	Acid as malic	Total astringency	Tannin	Non-tannin astringency	Total solids
Fruiting 4 years—Continued.										
Newtown Spitzenburg.	Oct. 3, 1922	Oct. 5	7.22	2.96	10.18	0.510	0.0771	0.0228	0.0543	------
	Oct. 4, 1923	Nov. 10	7.44	3.87	11.31	.367	.0852	.0442	.0410	14.02
	Oct. 18, 1924	Nov. 25	6.31	1.61	7.92	.325	.0702	.0314	.0388	------
	Sept. 25, 1925	Oct. 17	7.02	2.98	10.00	.273	.0760	.0302	.0458	11.88
Paragon	Sept. 2, 1921	Oct. 3	9.02	2.64	11.66	.507	------	------	------	13.71
	Oct. 26, 1923	Nov. 5	8.10	3.79	11.89	.384	.1260	.0480	.0780	------
	Nov. 4, 1924	Nov. 22	6.00	2.26	8.26	.332	.0955	.0355	.0600	------
	Nov. 6, 1925	Nov. 25	10.58	2.30	12.88	.308	.1205	.0601	.0604	13.47
Pawpaw	Aug. 29, 1922	Sept. 16	7.41	3.55	10.96	.611	.1174	.0505	.0669	13.87
	Sept. 28, 1923	Nov. 24	8.50	4.27	12.77	.885	.1110	.0400	.0710	15.70
	Sept. 24, 1924	Oct. 3	5.90	3.24	9.14	.623	.0945	.0165	.0780	------
	Oct. 1, 1925	Oct. 12	8.22	3.89	12.11	.482	.1170	.0453	.0717	14.67
Peck Pleasant	Oct. 3, 1921	Nov. 4	10.10	2.07	12.17	.568	------	------	------	------
	Oct. 19, 1923	Oct. 29	7.38	6.46	13.84	.480	.0940	.0418	.0522	14.97
	Oct. 11, 1924	Oct. 21	9.16	2.10	11.26	.570	.1100	.0465	.0635	------
	Oct. 7, 1925	Nov. 18	8.63	2.77	11.40	.292	.1125	.0405	.0720	13.02
Piper	Aug. 13, 1920	Aug. 26	8.24	2.66	10.90	.628	------	------	------	------
	June 27, 1922	June 30	8.85	.50	9.35	.564	.1614	.0408	.1206	10.67
	July 10, 1923	July 30	6.40	2.40	8.80	.580	.2180	.1010	.1170	10.46
	July 23, 1924	---do-----	5.86	1.02	6.88	.353	.1370	.0545	.0825	------
Rabum	Sept. 23, 1922	Nov. 16	8.81	1.77	10.58	.207	.0989	.0656	.0333	13.74
	Sept. 15, 1923	Dec. 5	8.88	2.80	11.68	.362	.1010	.0497	.0513	13.54
	Sept. 7, 1924	Sept. 20	6.85	2.09	8.94	.274	.0980	.0490	.0490	------
	Sept. 23, 1925	Sept. 26	8.06	2.40	10.46	.365	.1011	.0443	.0568	13.84
Ramsdell Sweet	Aug. 18, 1920	Sept. 11	9.62	2.00	11.62	.227	------	------	------	------
	Sept. 1, 1922	Sept. 5	9.03	2.15	11.18	.253	.1320	.0388	.0932	13.25
	Sept. 13, 1924	Sept. 24	8.08	2.78	10.86	.118	.1605	.0575	.1030	------
	Oct. 7, 1925	Oct. 16	8.12	1.78	9.90	.078	.1460	.0475	.0985	12.10
Rome Beauty	Oct. 7, 1922	Oct. 9	6.62	3.79	10.41	.360	.0877	.0264	.0613	11.99
	Oct. 9, 1923	Oct. 18	6.88	5.23	12.11	.392	.0720	.0164	.0556	13.41
	Nov. 4, 1924	Nov. 29	6.20	2.02	8.22	.264	.0836	.0146	.0690	11.62
	Sept. 23, 1925	Nov. 3	5.99	2.73	8.72	.273	.0993	.0329	.0664	11.28
Ronk	Sept. 18, 1922	Nov. 18	7.64	2.52	10.16	.524	.1187	.0256	.0931	12.96
	Oct. 8, 1923	Oct. 12	7.50	5.58	13.08	.720	.0925	.0315	.0610	14.81
	Oct. 11, 1924	Oct. 22	6.00	3.21	9.21	.566	.1095	.0455	.0640	------
	Sept. 23, 1925	Oct. 23	5.60	2.67	8.27	.390	.0760	.0300	.0460	10.48
Roxbury Russet	Oct. 4, 1920	Nov. 2	9.13	2.75	11.88	.557	------	------	------	13.03
	Oct. 4, 1923	Nov. 5	6.29	5.98	12.27	.614	.1130	.0471	.0659	16.84
	Oct. 8, 1924	Oct. 22	6.16	3.94	10.10	.532	.0945	.0373	.0572	------
	Oct. 1, 1925	Oct. 14	8.60	4.60	13.20	.502	.1200	.0365	.0835	16.41
Salome	Sept. 23, 1922	Dec. 9	8.80	1.60	10.40	.654	.0466	.0090	.0376	13.25
	Oct. 20, 1923	Oct. 23	8.41	4.79	13.20	.667	.0831	.0299	.0532	14.08
	Oct. 8, 1924	Oct. 10	7.58	2.98	10.56	.773	.0970	.0190	.0780	------
	Sept. 15, 1925	---do-----	10.06	2.15	12.21	.482	.0927	.0285	.0642	------
Santa	Oct. 20, 1922	Oct. 30	7.12	3.04	10.16	.421	.1168	.0496	.0672	11.05
	Oct. 26, 1923	Nov. 2	7.36	2.97	10.33	.745	.0720	.0310	.0410	12.12
	Nov. 5, 1924	Dec. 2	7.45	1.37	8.82	.652	.0945	.0177	.0768	------
	Oct. 16, 1925	Oct. 31	6.66	2.92	9.58	.628	.0722	.0232	.0492	12.18
Scott Winter	Sept. 23, 1922	Sept. 26	6.73	3.39	10.12	1.030	.0825	.0434	.0391	12.36
	Oct. 4, 1923	Nov. 5	6.56	3.62	10.18	.930	.1029	.0370	.0659	12.16
	Sept. 27, 1924	Oct. 4	10.26	6.30	16.56	.976	.1030	.0403	.0627	18.33
	Sept. 22, 1925	Oct. 16	7.22	2.25	9.47	.712	.1108	.0398	.0710	12.26
Shoemaker	July 16, 1922	July 19	6.44	1.78	8.22	.600	.1124	.0102	.1022	11.54
	July 20, 1923	July 23	6.06	2.58	8.64	.747	.1095	.0193	.0902	10.22
	July 29, 1924	Aug. 7	7.80	2.08	9.88	.374	.1535	.0598	.0937	------
	July 21, 1925	Aug. 1	6.54	3.20	9.74	.383	.1140	.0540	.0600	------

TABLE 1.—*Analytical results for the juices of 216 varieties of apples analyzed in three to six of the years 1920–1925*—Continued

Variety	Date picked	Date of analysis	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar after inversion	Acid as malic	Total astringency	Tannin	Non-tannin astringency	Total solids
Fruiting 4 years—Continued.										
Smith	Aug. 19, 1921	Sept. 5	8.64	2.93	11.57	0.453				
	Aug. 14, 1922	Aug. 16	9.98	2.38	12.36	.583	0.1267	0.0439	0.0828	13.36
	Aug. 29, 1923	Sept. 5	10.34	2.16	12.50	.475	.1200	.0595	.0605	14.60
	Aug. 29, 1924	Sept. 10	8.00	1.77	9.77	.337	.1017	.0587	.0430	13.29
Springdale	Oct. 28, 1920	Nov. 1	7.72	1.11	8.83	.660				11.20
	Oct. 20, 1922	Oct. 24	7.45	2.73	10.18	.454	.1274	.0557	.0717	13.84
	Oct. 20, 1923	Oct. 31	8.44	4.28	12.72	.558	.1535	.0395	.1140	13.98
	Nov. 4, 1924	Dec. 2	7.70	1.66	9.36	.325	.1290	.0487	.0803	
Stanard	Sept. 1, 1920	Sept. 11	8.09	1.20	9.29	.550				
	Aug. 19, 1922	Aug. 25	7.20	2.39	9.59	.553	.1011	.0214	.0797	11.80
	Sept. 3, 1923	Sept. 12	8.04	2.74	10.78	.426	.1330	.0550	.0780	11.83
	Sept. 15, 1924	Sept. 24	6.00	2.92	8.92	.400	.1210	.0564	.0646	
Striped Pippin	Oct. 4, 1920	Nov. 2	7.46	2.93	10.39	.680				11.76
	Sept. 23, 1922	Nov. 1	6.14	3.09	9.23	.710	.1478	.0673	.0805	10.81
	Sept. 3, 1923	Oct. 8	7.58	3.20	10.78	.468	.0918	.0395	.0523	13.66
	Oct. 1, 1925	Oct. 14	6.94	2.07	9.01	.371	.1185	.0521	.0664	12.34
Stuart	Sept. 13, 1921	Oct. 6	6.31	3.64	9.95	.711				
	Oct. 13, 1922	Oct. 14	5.78	3.98	9.76	.545	.0842	.0325	.0517	11.25
	Oct. 8, 1923	Nov. 17	5.60	4.10	9.70	.356	.0727	.0213	.0514	11.36
	Sept. 25, 1925	Oct. 20	7.70	3.84	11.54	.357	.0868	.0284	.0584	13.45
Sweet Romanite	Oct. 11, 1921	Nov. 3	9.98	4.13	14.11	.303				
	Oct. 10, 1922	Oct. 17	8.25	6.28	14.53	.193	.1070	.0421	.0649	16.55
	Oct. 12, 1923	Oct. 19	8.00	5.14	13.14	.342	.1140	.0202	.0938	14.26
	Oct. 18, 1924	Nov. 1	7.70	5.40	13.10	.163	.1130	.0260	.0870	
Terry	Sept. 2, 1921	Sept. 24	8.16	2.75	10.91	.662				
	Oct. 22, 1922	Oct. 24	5.98	4.55	10.53	.786	.1133	.0275	.0858	13.66
	Oct. 26, 1923	Oct. 31	5.90	6.24	12.14	.746	.1232	.0460	.0772	16.40
	Nov. 4, 1924	Nov. 15	5.72	6.39	12.11	.667	.1217	.0422	.0795	
Twisty	Aug. 6, 1921	Aug. 30	8.78	.70	9.48	.500				
	Aug. 11, 1922	Aug. 14	10.02	.19	10.21	1.023	.0848	.0092	.0756	12.68
	Aug. 23, 1923	Aug. 30	7.73	1.08	8.81	.487	.0606	.0203	.0403	10.97
	Sept. 1, 1924	Sept. 4	6.22	1.04	7.26	.332	.0692	.0175	.0417	10.18
Victoria Sweet	Aug. 19, 1922	Aug. 21	7.14	4.20	11.34	.444	.0909	.0266	.0643	13.33
	Aug. 23, 1923	Sept. 5	7.93	2.84	10.77	.249	.1282	.0571	.0711	12.78
	Sept. 13, 1924	Sept. 18	7.96	3.38	11.34	.178	.1190	.0457	.0733	
	Sept. 5, 1925	Sept. 14	8.10	2.98	11.08	.124	.1210	.0576	.0634	13.76
Wallace Howard	Sept. 23, 1922	Nov. 8	7.20	3.38	10.58	.330	.1371	.0964	.0407	
	Sept. 28, 1923	Nov. 30	7.06	3.25	10.31	.326	.0982	.0460	.0522	13.04
	Sept. 15, 1924	Oct. 3	5.90	3.24	9.14	.410	.0980	.0457	.0523	
	Sept. 16, 1925	Oct. 8	7.96	3.42	11.38	.292	.1070	.0504	.0566	13.42
Weaver	Sept. 23, 1922	Nov. 17	6.52	1.86	8.38	.154	.0908	.0271	.0637	11.54
	Sept. 8, 1923	Sept. 24	7.64	4.05	11.69	.221	.1150	.0570	.0580	13.00
	Oct. 1, 1924	Oct. 6	6.72	3.20	9.92	.208	.1090	.0360	.0730	
	Sept. 22, 1925	Sept. 24	7.76	2.59	10.35	.156	.1127	.0495	.0632	13.07
Wells	Sept. 28, 1922	Nov. 14	6.69	3.15	9.84	.406	.0770	.0133	.0637	12.19
	Sept. 13, 1923	Nov. 28	6.83	3.06	9.89	.376	.0779	.0293	.0486	11.02
	Sept. 13, 1924	Sept. 18	5.35	3.04	8.39	.621	.0567	.0267	.0300	
	Oct. 1, 1925	Oct. 14	6.40	2.12	8.52	.417	.0710	.0168	.0542	10.30
Willow	Sept. 24, 1921	Oct. 16	9.02	2.32	11.34	.444				
	Sept. 25, 1922	Sept. 30	5.84	2.98	8.82	.682	.0799	.0304	.0495	11.58
	Oct. 12, 1923	Oct. 20	6.02	5.38	11.40	.587	.0960	.0249	.0711	12.19
	Oct. 4, 1924	Oct. 30	6.00	4.28	10.28	.577	.1080	.0357	.0723	
Wingate	Aug. 15, 1922	Aug. 17	7.39	1.15	8.54	.794	.1390	.0389	.1001	10.94
	Aug. 29, 1923	Sept. 11	5.86	2.03	7.89	.462	.1010	.0518	.0492	9.63
	Aug. 29, 1924	Sept. 4	7.14	2.78	9.92	.503	.1222	.0454	.0768	
	Sept. 1, 1925	...do.....	5.72	2.34	8.06	.424	.0920	.0355	.0565	11.18

See footnote at end of table.

TABLE 1.—*Analytical results for the juices of 216 varieties of apples analyzed in three to six of the years 1920–1925*—Continued

Variety	Date picked	Date of analysis	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar after inversion	Acid as malic	Total astringency	Tannin	Non-tannin astringency	Total solids
Fruiting 4 years—Continued.										
Winter Banana	Aug. 22, 1921	Sept. 19	7.40	3.45	10.85	0.293				
	Sept. 6, 1922	Sept. 13	6.63	4.10	10.73	.317	0.1181	0.0634	0.0547	12.42
	Sept. 5, 1923	...do...	8.20	2.33	10.53	.371	.1530	.0540	.0990	12.02
	Sept. 18, 1925	Oct. 5	9.16	1.68	10.84	.182	.1390	.0570	.0820	13.18
Winter Paradise	Oct. 16, 1922	Oct. 18	8.76	1.20	9.96	.114	.1447	.0860	.0587	12.04
	Oct. 19, 1923	Oct. 25	8.84	3.34	12.18	.132	.1435	.0759	.0676	14.15
	Oct. 28, 1924	Nov. 1	7.02	2.40	9.42	.107	.1667	.0595	.1072	.....
	Oct. 10, 1925	Oct. 31	9.32	2.16	11.48	.092	.1620	.0670	.0950	13.84
Yellow Transparent.	June 26, 1922	June 30	6.34	1.56	7.90	.680	.1942	.1125	.0817	9.24
	July 9, 1923	July 18	7.35	2.07	9.42	1.400	.2270	.0876	.1394	12.17
	July 23, 1924	July 30	5.31	.77	6.08	.439	.1360	.0380	.0980	9.69
	July 11, 1925	July 17	5.92	1.61	7.53	.486	.0753	.0255	.0498	.....
Yopp	Oct. 19, 1922	Oct. 20	7.62	2.91	10.53	.329	.0947	.0345	.0602	11.92
	Sept. 28, 1923	Oct. 2	6.86	3.65	10.51	.314	.0813	.0221	.0592	12.32
	Sept. 24, 1924	Oct. 7	6.20	2.76	8.96	.374	.1280	.0655	.0625	.....
	Sept. 25, 1925	Sept. 27	7.12	1.75	8.87	.274	.0920	.0429	.0491	11.23
York Imperial	Sept. 13, 1921	Oct. 16	9.00	2.04	11.04	.588				
	Sept. 25, 1922	Oct. 12	10.71	1.58	12.29	.491	.0657	.0050	.0607	13.49
	Nov. 1, 1923	Nov. 2	8.36	4.12	12.48	.467	.0770	.0315	.0455	14.80
	Oct. 14, 1924	Oct. 17	7.13	2.43	9.56	.463	.0516	.0136	.0380	.....
Fruiting 3 years:										
All-Summer	July 27, 1920	Aug. 3	7.30	1.04	8.34	.631				10.00
	July 20, 1922	July 21	6.07	1.97	8.04	.466	.1287	.0296	.0991	.....
	Aug. 2, 1923	Aug. 6	7.34	4.05	11.39	.895	.1410	.0840	.0570	12.39
Alton	Oct. 10, 1922	Oct. 12	6.44	4.00	10.44	.634	.0771	.0140	.0631	12.54
	Oct. 12, 1923	Oct. 25	6.06	2.72	8.80	.374	.0472	.0180	.0292	9.48
	Oct. 4, 1924	Oct. 17	7.31	1.24	8.55	.570	.0487	.0127	.0360	.....
Arkansas Beauty	Oct. 26, 1923	Nov. 2	7.64	4.12	11.76	.460	.0944	.0482	.0462	15.20
	Oct. 8, 1924	Oct. 16	7.00	2.88	9.88	.515	.0865	.0325	.0540	.....
	Oct. 14, 1925	Nov. 7	7.04	2.86	9.90	.338	.0980	.0522	.0458	11.91
Baltimore	Sept. 23, 1922	Nov. 1	7.66	2.58	10.24	.241	.1212	.0336	.0876	.....
	Oct. 12, 1923	Oct. 18	8.20	4.70	12.90	.382	.0900	.0283	.0617	14.49
	Oct. 18, 1924	Oct. 23	6.12	2.18	8.30	.242	.0952	.0344	.0608	.....
Barnes	Sept. 20, 1921	Oct. 19	8.64	4.13	12.77	.456				.....
	Oct. 20, 1924	Nov. 8	8.88	3.02	11.90	.290	.1130	.0480	.0650	.....
	Oct. 7, 1925	Nov. 21	9.32	2.60	11.92	.218	.1152	.0320	.0832	14.10
Baxter	Sept. 13, 1923	Sept. 27	6.94	3.87	10.81	.634	.1010	.0308	.0702	13.06
	Sept. 13, 1924	Oct. 7	4.80	2.24	7.04	.340	.0780	.0257	.0523	.....
	Sept. 17, 1925	Sept. 24	7.02	2.30	9.32	.352	.0932	.0414	.0518	11.81
Bismarck	Aug. 12, 1921	Sept. 6	8.16	3.13	11.29	.427				
	Sept. 28, 1922	Dec. 14	7.86	2.02	9.88	.688	.0826	.0227	.0599	10.57
	Oct. 8, 1924	Oct. 15	8.63	.41	9.04	.630	.1435	.0550	.0885	11.51
Blenheim	Sept. 13, 1922	Dec. 12	7.05	4.65	11.70	.646	.0650	.0237	.0413	13.02
	Sept. 13, 1923	Nov. 21	7.10	7.01	14.11	.870	.1455	.0721	.0734	16.00
	Oct. 8, 1924	Oct. 21	6.64	4.58	11.22	.590	.0945	.0423	.0522	.....
Brown (Nottingham Brown.)	Sept. 23, 1922	Nov. 18	8.30	2.86	11.16	.515	.1056	.0194	.0860	14.50
	Oct. 8, 1923	Oct. 17	7.67	3.87	11.54	.482	.0916	.0299	.0617	14.56
	Oct. 4, 1924	Oct. 20	7.76	3.00	10.76	.590	.1010	.0470	.0540	.....
Buckingham	Sept. 23, 1922	Dec. 9	7.65	2.05	9.70	.431	.0448	.0343	.0105	12.19
	Sept. 27, 1923	Oct. 8	6.26	3.39	9.65	.456	.0994	.0463	.0531	11.67
	Oct. 14, 1924	Oct. 17	6.00	1.42	7.42	.356	.0780	.0335	.0445	.....
Colton	July 15, 1920	July 28	8.54	.42	8.96	.641				.....
	June 10, 1922	June 30	7.54	.70	8.24	.713	.2095	.0716	.1379	10.31
	July 23, 1924	July 30	4.65	1.57	6.22	.429	.0970	.0340	.0630	.....
Colvert	Aug. 11, 1922	Aug. 14	8.46	2.39	10.85	.769	.1553	.0552	.1001	14.63
	Sept. 16, 1923	Nov. 22	6.08	3.16	9.24	.425	.1455	.0685	.0770	11.16
	Sept. 15, 1924	Sept. 19	6.49	2.83	9.32	.494	.1082	.0392	.0690	.....

TABLE 1.—*Analytical results for the juices of 216 varieties of apples analyzed in three to six of the years 1920–1925*—Continued

Variety	Date picked	Date of analysis	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar after inversion	Acid as malic	Total astringency	Tannin	Non-tannin astringency	Total solids
Fruiting 3 years—Continued.										
Cotter	Sept. 23, 1922	Dec. 14	8.36	1.88	10.24	0.532	0.0668	0.0185	0.0483	12.52
	Oct. 9, 1923	Oct. 18	7.58	3.08	10.66	.466	.0617	.0172	.0445	12.51
	Oct. 4, 1924	Oct. 6	7.02	2.91	9.93	.458	.0935	.0412	.0523	------
Covert	Sept. 28, 1922	Nov. 16	9.66	1.20	10.86	.244	.0832	.0368	.0464	13.23
	Sept. 9, 1923	Oct. 18	9.26	2.24	11.50	.316	.1130	.0495	.0635	13.68
	Sept. 16, 1924	Oct. 8	8.26	1.10	9.36	.349	.0978	.0236	.0742	------
Cox No. 11	Aug. 14, 1922	Aug. 17	7.60	3.58	11.18	.708	.1093	.0450	.0643	12.30
	Aug. 17, 1923	...do....	6.48	2.41	8.89	.922	.0728	.0303	.0425	10.19
	Aug. 18, 1924	Aug. 25	5.76	2.58	8.34	.706	.0417	.0157	.0260	------
Cross	Aug. 12, 1922	Aug. 15	7.82	1.20	9.02	.515	.1482	.0665	.0817	12.55
	Sept. 8, 1923	Sept. 19	8.26	2.57	10.83	.346	.1485	.0645	.0840	13.35
	Aug. 29, 1924	Sept. 10	7.49	2.04	9.53	.439	.1353	.0798	.0555	13.16
Daniel	Aug. 7, 1922	Aug. 8	8.31	3.78	12.09	.632	.1338	.0316	.1022	13.09
	Aug. 20, 1923	Aug. 24	7.47	3.20	10.67	.452	.0985	.0353	.0632	11.97
	Aug. 29, 1924	Sept. 6	8.04	3.02	11.06	.311	.0847	.0305	.0542	------
Early Richmond	July 16, 1922	July 18	5.39	3.25	8.64	.861	.0868	.0122	.0746	9.69
	July 14, 1923	...do....	5.95	2.79	8.74	1.334	.1026	.0256	.0770	------
	July 28, 1924	Aug. 4	5.24	2.37	7.61	.967	.0855	.0222	.0633	------
Family	Aug. 23, 1922	Sept. 5	7.90	.22	8.12	.837	.0776	.0172	.0604	9.86
	Sept. 13, 1923	Sept. 27	6.00	5.09	11.09	.800	.0835	.0205	.0630	------
	Sept. 23, 1924	Oct. 2	3.76	3.10	6.86	.505	.0515	.0075	.0440	------
Gano	Sept. 10, 1921	Oct. 11	6.25	2.93	9.18	.510	------	------	------	------
	Oct. 3, 1922	Oct. 10	7.44	2.64	10.08	.406	.1043	.0324	.0719	11.73
	Sept. 28, 1923	Dec. 3	7.38	3.53	10.91	.321	.1094	.0500	.0594	11.62
Gideon	Aug. 18, 1920	Sept. 16	8.94	1.08	10.02	.678	------	------	------	------
	Oct. 3, 1922	Oct. 6	7.62	2.55	10.17	.456	.0956	.0477	.0479	12.31
	Sept. 5, 1924	Sept. 19	7.46	1.02	8.48	.362	.1080	.0605	.0475	------
Golden Pippin	Aug. 8, 1922	Aug. 10	6.80	2.02	8.82	.658	.0991	.0184	.0807	11.65
	Aug. 13, 1923	Aug. 16	5.89	4.69	10.58	.632	.1020	.0406	.0614	10.79
	Aug. 29, 1924	Sept. 3	6.11	1.89	8.00	.313	.0904	.0181	.0723	------
Golden Sweet	July 31, 1920	Aug. 6	8.86	1.12	9.98	.144	.1280	.0460	.0820	11.40
	July 25, 1922	July 26	8.37	1.20	9.57	.276	.1768	.0521	.1247	------
	Aug. 2, 1923	Aug. 6	6.09	3.43	9.52	.200	.1880	.0845	.1035	10.72
Grosh	Sept. 6, 1922	Dec. 11	9.12	2.54	11.66	.341	.0527	.0132	.0395	14.14
	Sept. 16, 1923	Nov. 12	6.68	5.64	12.32	.488	.1233	.0668	.0565	16.54
	Sept. 13, 1924	Sept. 25	5.58	2.52	8.10	.405	.0830	.0258	.0572	------
Heidemeyer	Sept. 6, 1922	Sept. 15	9.22	1.60	10.82	.557	.0975	.0406	.0569	12.85
	Aug. 29, 1923	Sept. 5	7.02	4.18	11.20	.488	.1175	.0465	.0710	14.08
	Sept. 7, 1924	Sept. 16	6.36	3.94	10.30	.494	.1190	.0775	.0415	------
Henry Clay	July 6, 1922	July 7	6.54	1.08	7.62	.972	.1471	.0521	.0950	------
	July 6, 1923	July 13	5.92	2.96	8.88	.595	.1221	.0591	.0630	10.49
	Aug. 4, 1924	Aug. 4	5.24	1.36	6.60	.373	.1050	.0285	.0765	------
Hogg	Aug. 3, 1922	...do....	6.80	2.71	9.51	1.454	.2023	.0828	.1195	13.14
	Aug. 14, 1923	Aug. 21	8.30	5.44	13.74	2.259	.1560	.0743	.0817	14.99
	Sept. 2, 1924	Sept. 15	6.11	3.93	10.04	1.066	.1262	.0690	.0572	------
Indiana Favorite	Sept. 23, 1922	Nov. 16	7.55	1.99	9.54	.344	.0788	.0455	.0333	13.73
	Oct. 12, 1923	Oct. 30	7.44	4.99	12.43	.318	.0745	.0283	.0462	13.71
	Oct. 18, 1924	...do.....	7.84	4.94	12.78	.388	.0690	.0210	.0480	------
Irish Peach	July 22, 1920	July 30	6.03	2.00	8.03	.520	------	------	------	------
	July 14, 1922	July 17	5.80	1.93	7.73	.581	.1390	.0511	.0879	11.10
	July 10, 1923	July 18	5.85	1.30	7.15	.552	.2750	.1210	.1540	------
Julian de Paulmier.	Sept. 3, 1923	Sept. 19	9.52	3.38	12.90	.350	.6100	.3200	.2900	15.61
	Sept. 7, 1924	Sept. 18	8.35	3.37	11.72	.185	.4720	.1580	.3140	------
	Oct. 5, 1925	Oct. 12	8.80	3.52	12.32	.182	.3260	.0860	.2400	15.09

TABLE 1.—*Analytical results for the juices of 216 varieties of apples analyzed in three to six of the years 1920–1925*—Continued

Variety	Date picked	Date of analysis	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar after inversion	Acid as malic	Total astringency	Tannin	Non-tannin astringency	Total solids
Fruiting 3 years—Continued.										
Kay	Aug. 18, 1921	Sept. 16	6.04	1.43	7.47	0.582	0.1113	0.0136	0.0977	.....
	Sept. 5, 1923	Sept. 14	6.56	2.65	9.21	.562	.1160	.0520	.0640	9.60
	Sept. 15, 1924	Oct. 2	7.10	2.04	9.14	.445	.1335	.0695	.0640	.....
King David	Aug. 30, 1921	Nov. 1	7.79	2.91	10.70	.372	.....	.....	.....	.....
	Sept. 23, 1922	Nov. 17	7.79	4.52	12.31	.561	.0749	.0263	.0486	15.56
	Sept. 19, 1923	Nov. 16	9.28	4.42	13.70	.651	.0692	.0092	.0600	14.48
Melo Gelato	Oct. 13, 1922	Oct. 16	8.27	2.08	10.35	.279	.0833	.0377	.0456	12.30
	Oct. 12, 1923	Oct. 26	8.69	3.07	11.76	.238	.1430	.0726	.0704	15.08
	Oct. 28, 1924	Nov. 15	7.66	1.82	9.48	.206	.0937	.0439	.0498	.....
Milam	Sept. 25, 1920	Oct. 2	8.00	.56	8.56	.568	.0795	.0218	.0577	11.02
	Aug. 30, 1921	Sept. 16	7.92	4.18	12.10	.668	.0820	.0144	.0676	.....
	Sept. 23, 1923	Oct. 2	6.72	3.66	10.38	.650	.1000	.0377	.0623	12.57
Munson	Aug. 14, 1920	Aug. 17	7.46	1.75	9.21	.230	.0930	.0180	.0750	.....
	Aug. 4, 1922	Aug. 7	8.21	2.48	10.69	.254	.1768	.0317	.1451	11.29
	Aug. 16, 1923	Aug. 24	7.22	4.47	11.69	.246	.1050	.0400	.0650	13.30
Muster	Aug. 15, 1922	Aug. 16	8.92	2.10	11.02	.365	.1246	.0388	.0858	12.86
	Aug. 13, 1923	Aug. 21	8.13	3.04	11.17	.390	.1310	.0685	.0625	13.09
	Sept. 5, 1924	Sept. 15	7.30	3.03	10.33	.217	.1452	.1025	.0427	.....
Northern Spy	Sept. 28, 1922	Nov. 3	8.12	2.86	10.98	.393	.1239	.0425	.0814	13.09
	Aug. 29, 1924	Oct. 8	6.54	3.16	9.70	.567	.1055	.0403	.0652	.....
	Sept. 16, 1925	Sept. 22	8.06	3.32	11.38	.495	.1340	.0656	.0684	13.61
Oakland	Sept. 6, 1922	Sept. 20	8.00	1.59	9.59	.233	.0738	.0243	.0495	12.34
	Sept. 19, 1923	Nov. 14	8.00	4.26	12.26	.284	.1045	.0464	.0581	15.04
	Sept. 13, 1924	Sept. 24	6.46	1.80	8.26	.279	.0604	.0149	.0455	.....
Ohio Nonpareil	Aug. 23, 1922	Aug. 28	7.88	2.74	10.62	.522	.1104	.0431	.0673	14.29
	Sept. 15, 1924	Sept. 22	6.20	3.22	9.42	.265	.0880	.0348	.0532	.....
	Aug. 28, 1925	Sept. 24	5.28	2.55	7.83	.163	.0725	.0325	.0400	9.27
Ortley	Sept. 23, 1922	Sept. 23	6.04	3.23	9.27	.522	.0634	.0348	.0286	11.42
	Sept. 27, 1923	Sept. 29	8.00	3.24	11.24	.732	.0842	.0342	.0500	13.24
	Oct. 8, 1924	Oct. 21	7.64	2.29	9.93	.400	.0713	.0318	.0395	.....
Ozone	Sept. 28, 1922	Nov. 4	8.07	2.51	10.58	.342	.1248	.0319	.0929	12.93
	Sept. 27, 1923	Oct. 10	8.92	4.39	13.31	.558	.1003	.0206	.0797	16.29
	Oct. 1, 1924	Oct. 9	7.28	2.64	9.92	.540	.0660	.0275	.0685	.....
Patten	Aug. 24, 1920	Sept. 17	6.40	.92	7.32	.678	.0513	.0113	.0400	9.64
	Aug. 15, 1922	Aug. 18	7.55	1.47	9.02	.964	.1226	.0347	.0879	.....
	Sept. 24, 1924	Oct. 2	5.38	1.58	6.96	.630	.1250	.0578	.0672	.....
Pinnacle	Sept. 2, 1921	Sept. 24	8.08	3.40	11.48	.863	.0878	.0110	.0768	.....
	Sept. 13, 1922	Oct. 7	7.33	2.28	9.61	.647	.1131	.0517	.0614	12.32
	Oct. 7, 1925	Nov. 21	6.76	3.08	9.84	.430	.1270	.0385	.0885	11.40
Précoce de Tunis	July 21, 1920	July 25	6.80	1.54	8.34	.190	.2239	.0714	.1525	.....
	July 13, 1922	July 18	6.24	1.89	8.13	.348	.1635	.0716	.0919	9.51
	July 16, 1923	July 26	7.76	3.87	11.63	.358	.3910	.1900	.2010	13.92
Primate	July 20, 1922	July 21	6.22	3.52	9.74	.478	.1287	.0310	.0977	10.94
	July 20, 1923	July 23	7.34	2.58	9.92	.890	.1424	.0887	.0537	11.32
	Aug. 6, 1924	Aug. 11	7.26	.38	7.64	1.385	.0740	.0318	.0422	.....
Rambo	Sept. 2, 1920	Sept. 23	8.90	2.01	10.91	.388	.0920	.0352	.0568	12.88
	Oct. 20, 1923	Oct. 26	9.48	4.06	13.54	.402	.1002	.0445	.0557	14.84
	Sept. 14, 1924	Sept. 19	6.76	1.70	8.46	.398	.0795	.0070	.0725	.....
Rebel	Sept. 23, 1922	Oct. 13	7.36	3.22	10.58	.253	.0841	.0275	.0566	13.31
	Sept. 27, 1923	....do.....	7.38	4.44	11.82	.341	.0615	.0201	.0414	13.58
	Sept. 26, 1924	Oct. 3	6.16	3.52	9.68	.325	.0733	.0284	.0499	.....
Red June	July 15, 1922	July 17	6.01	1.84	7.85	.551	.1584	.0603	.0981	10.56
	July 20, 1923	July 23	6.06	2.93	8.99	.686	.1373	.0713	.0660	10.30
	July 28, 1924	Aug. 13	6.54	2.43	8.97	.350	.1180	.0390	.0790	.....

TABLE 1.—*Analytical results for the juices of 216 varieties of apples analyzed in three to six of the years 1920–1925*—Continued

Variety	Date picked	Date of analysis	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar after inversion	Acid as malic	Total astringency	Tannin	Non-tannin astringency	Total solids
Fruiting 3 years—Continued.										
Red Keeper	Oct. 26, 1922	Oct. 29	8.32	2.80	11.12	0.220	0.1292	0.0531	0.0761	13.55
	Nov. 4, 1924	Dec. 2	7.88	2.62	10.50	.296	.1104	.0242	.0862	.....
	Oct. 12, 1925	Nov. 25	5.88	3.21	9.09	.208	.0800	.0300	.0500	9.83
Red Siberian	Aug. 1, 1922	Aug. 7	9.24	4.06	13.30	1.351	.5283	.2340	.2943	16.36
	Sept. 3, 1923	Sept. 18	8.18	4.80	12.98	.938	.6600	.4320	.2280	16.22
	Sept. 10, 1924	Sept. 16	7.49	2.13	9.62	.605	.5450	.3985	.1465	.....
Reynard	Sept. 1, 1922	Sept. 5	8.96	.98	9.94	.685	.0794	.0346	.0448	12.45
	Sept. 3, 1923	Sept. 11	7.96	1.13	9.09	.518	.0905	.0194	.0711	11.63
	Aug. 9, 1924	Sept. 4	7.99	2.47	10.46	.480	.0880	.0202	.0678	.....
Ruby Gem	July 25, 1922	July 26	6.44	1.95	8.39	.769	.1635	.0399	.1236	10.72
	Aug. 1, 1923	Sept. 12	6.00	4.94	10.94	.676	.1680	.0643	.1037	12.73
	Aug. 11, 1924	Aug. 25	6.66	1.84	8.50	.400	.1172	.0584	.0588	.....
Rymer	Aug. 28, 1920	Sept. 28	7.18	.80	7.98	.698	.0752	.0210	.0542	12.18
	Sept. 23, 1923	Dec. 8	6.66	2.44	9.10	.522	.0836	.0199	.0637	10.78
	Oct. 4, 1924	Oct. 11	6.74	2.34	9.08	.573	.1235	.0567	.0668	.....
Schroder	Nov. 1, 1920	Nov. 8	6.36	.68	7.04	.705	.0665	.0219	.0446	.....
	Oct. 4, 1923	...do.....	8.52	2.58	11.10	.835	.1170	.0528	.0642	14.62
	Oct. 28, 1924	Nov. 25	6.82	2.20	9.02	.427	.0878	.0363	.0515	11.86
Sierra Beauty	Sept. 23, 1922	Dec. 13	6.92	5.02	11.94	.837	.0677	.0184	.0493	14.22
	Oct. 12, 1923	Oct. 23	6.58	4.78	11.36	.602	.0695	.0165	.0530	12.83
	Oct. 21, 1924	...do.....	7.02	2.28	9.30	.657	.0715	.0185	.0530	.....
Spencer Seedling	Oct. 5, 1922	Oct. 13	9.97	2.81	12.78	.360	.1105	.0369	.0736	15.16
	Oct. 12, 1923	Oct. 23	8.30	5.76	14.06	.303	.1480	.0690	.0790	14.55
	Oct. 18, 1924	Oct. 30	8.54	2.98	11.52	.265	.1080	.0255	.0825	.....
Spice	Aug. 14, 1920	Aug. 16	8.20	1.68	9.88	.810	.0734	.0129	.0605	.....
	Aug. 11, 1922	Aug. 13	7.65	2.51	10.16	.870	.1022	.0174	.0848	11.38
	Aug. 21, 1923	Aug. 27	6.62	4.90	11.52	.775	.1135	.0450	.0685	13.64
Stark	Oct. 15, 1922	Oct. 18	7.39	3.30	10.69	.416	.0649	.0412	.0237	12.67
	Oct. 26, 1923	Nov. 2	8.97	4.89	13.86	.481	.0984	.0368	.0616	15.58
	Oct. 21, 1924	Dec. 1	7.72	1.64	9.36	.291	.0885	.0345	.0540	11.29
Starkey	Aug. 30, 1922	Sept. 5	9.26	2.28	11.54	.606	.1113	.0052	.1061	14.66
	Sept. 15, 1923	Nov. 17	7.47	3.30	10.77	.495	.1030	.0508	.0522	13.78
	Sept. 5, 1924	Sept. 16	7.49	3.43	10.92	.434	.0915	.0393	.0522	.....
Stinson	Aug. 14, 1922	Aug. 16	8.82	1.68	10.50	.674	.0950	.0082	.0868	13.04
	Aug. 15, 1923	Aug. 17	7.88	2.50	10.38	.640	.0940	.0352	.0588	12.10
	Aug. 29, 1924	Sept. 3	7.60	3.30	10.90	.366	.1105	.0417	.0688	.....
Summer Pound	July 28, 1922	July 31	6.29	2.27	8.56	.733	.1001	.0225	.0776	10.96
	July 18, 1924	Aug. 25	5.88	3.00	8.88	.488	.0622	.0352	.0270	11.34
	Sept. 1, 1925	Sept. 4	5.14	2.49	7.63	.260	.0985	.0375	.0610	10.74
Townsend	July 28, 1922	July 31	6.26	2.95	9.21	.740	.1134	.0235	.0899	11.61
	Aug. 8, 1923	Aug. 13	7.06	3.37	10.43	.462	.0855	.0342	.0513	11.66
	Aug. 29, 1924	Sept. 6	8.14	2.96	11.10	.282	.0915	.0330	.0585	.....
Trader	July 28, 1922	July 31	6.87	2.01	8.88	.717	.1512	.0225	.1287	11.16
	Aug. 16, 1923	Aug. 24	8.34	4.92	13.26	.520	.2030	.1342	.0688	15.07
	Sept. 8, 1924	Sept. 8	7.38	2.96	10.34	.401	.1275	.0959	.0316	.....
Trumbull	Aug. 3, 1922	Aug. 7	8.34	1.85	10.19	.199	.1727	.0593	.1134	11.79
	Aug. 29, 1923	Sept. 5	9.18	3.75	12.93	.221	.1700	.0935	.0765	14.34
	Aug. 29, 1924	Sept. 12	6.86	3.02	9.88	.133	.1251	.0564	.0687	11.34
Utter	Aug. 23, 1922	Aug. 25	6.60	1.27	7.87	.482	.0848	.0174	.0674	10.77
	Sept. 5, 1923	Sept. 7	6.78	4.30	11.08	.534	.0975	.0275	.0700	11.19
	Sept. 5, 1924	Sept. 16	7.02	1.92	8.94	.319	.1150	.0610	.0540	.....
Wealthy	Aug. 11, 1922	Aug. 14	7.20	1.37	8.57	.709	.0848	.0061	.0787	10.37
	Aug. 23, 1923	Sept. 4	7.33	2.87	10.20	.622	.0796	.0203	.0593	11.79
	Aug. 29, 1924	Sept. 3	7.38	1.75	9.13	.665	.1140	.0575	.0565	11.20

TABLE 1.—*Analytical results for the juices of 216 varieties of apples analyzed in three to six of the years 1920–1925*—Continued

Variety	Date picked	Date of analysis	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total suger after inversion	Acid as malic	Total astringenty	Tannin	Non-tannin astringency	Total solids
Fruiting 3 years—Continued.										
White Pearmain	Oct. 19, 1922	Oct. 19	7.92	5.14	13.06	0.583	0.0973	0.0309	0.0664	15.65
	Oct. 26, 1923	Oct. 31	7.22	6.64	13.86	.590	.0968	.0368	.0600	15.93
	Oct. 4, 1924	Oct. 21	7.64	3.47	11.11	.575	.1020	.0380	.0640	------
Williams	July 25, 1923	July 30	6.67	4.10	10.77	.551	.1420	.0695	.0725	12.32
	July 29, 1924	Aug. 6	6.67	2.15	8.82	.296	.1275	.0606	.0669	------
	July 21, 1925	July 25	6.71	1.53	8.24	.387	.0856	.0311	.0545	------
Wilson June	Aug. 7, 1922	Aug. 9	7.51	3.42	10.93	.713	.1451	.0389	.1062	11.95
	Aug. 23, 1923	Aug. 30	7.40	2.52	9.92	.470	.1200	.0594	.0606	10.90
	Aug. 29, 1924	Sept. 2	6.26	3.03	9.29	.385	.0858	.0383	.0475	------
Winter Smokehouse[f]	Sept. 8, 1922	Nov. 4	8.15	3.37	11.52	.365	.1141	.0185	.0956	12.87
	Oct. 12, 1923	Nov. 14	7.65	4.13	11.78	.557	.1167	.0561	.0606	------
	Sept. 24, 1924	Oct. 8	7.33	1.92	9.25	.496	.1128	.0516	.0612	------
Wolseley	Oct. 13, 1922	Oct. 17	6.84	2.73	9.57	.697	.1000	.0430	.0570	12.90
	Oct. 12, 1923	Oct. 23	7.44	3.76	11.20	.730	.0945	.0295	.0650	12.74
	Oct. 18, 1924	Oct. 23	6.02	1.71	7.73	.692	.0675	.0246	.0429	------
Yellow Siberian	Aug. 1, 1922	Aug. 7	10.88	1.66	12.54	1.154	.4374	.1952	.2422	15.40
	Sept. 6, 1923	Sept. 18	6.67	4.53	11.20	1.010	.3450	.1982	.1468	13.02
	Aug. 29, 1924	Sept. 19	7.82	3.20	11.02	.593	.3760	.2335	.1425	------
Zoar	Aug. 2, 1921	Aug. 24	7.02	1.28	8.30	.722	------	------	------	------
	Aug. 7, 1922	Aug. 8	8.18	1.62	9.80	.975	.1471	.0368	.1103	11.02
	Aug. 21, 1923	Aug. 27	7.64	1.99	9.63	.454	.1150	.0598	.0552	10.64

[a] The material employed in these analyses was taken from two trees originally planted as ornamentals in the grounds of the Arlington farm. The seeds were taken by D. N. Shoemaker, of the Office of Horticulture, in 1909 or 1910 from a single tree which is still standing in a piece of waste land adjacent to the farm. The very exceptional characters of the fruit attracted attention to it and led to the making of annual analyses upon the crop of the younger trees and an occasional analysis of that of the parent tree. These agree in all essential respects The trees have been identified as *Pyrus angustifolia* by members of the Office of Horticulture.

[b] Two apples are known under this name. That here employed does not conform to the description given by Beach (7) but agrees closely in all respects with the description by Bunyard (9) and is believed to be the apple known in England under this name.

[c] The apple designated as Hort. No. 3050 was received as Jackson. It is clearly not that variety, but its identity is still in doubt.

[d] The apple designated as Hort. No. 4941 was received under the name of Herschel Cox. The fruit differs in so many respects from the available descriptions of that variety that its identity is in doubt. It is therefore designated by the serial number given it at its receipt by the Office of Horticulture.

[e] The apple designated as Smith is not Smith Cider, but a local variety originating in Kansas and never introduced into the trade.

[f] The apple designated as Winter Smokehouse is practically indistinguishable in appearance from Smokehouse, but has shown consistent differences in chemical composition which are believed to warrant regarding it as distinct from that variety.

ANALYTICAL RESULTS

All the analytical data obtained in the course of the work are presented together in Table 1. In order to examine these data for the presence or absence of any mass fluctuations in chemical composition occurring from year to year, it was necessary to make such analysis and rearrangement of the results as would permit comparison of the crop of any one year with that of all the other years. Such a rearrangement was complicated by the fact that while the analyses extended over 6 years, the varieties did not all fruit annually, so that the forms analyzed in any year consisted of groups analyzed in 6, 5, 4, and 3 years, respectively, of the possible 6. Each of the 5-year, 4-year, and 3-year groups had to be further subdivided into classes, each containing varieties which had been analyzed in the same years

in order that the comparisons made might be rigidly accurate. When this rearrangement of the data had been made, each of the various groups was examined with respect to the content of total sugars, sucrose, titratable acidity, and astringent constituents of its members in each of the years in which the particular group was subjected to analysis. In assembling the results, consideration was had for the fact that occurrence of large numbers of maximum or minimum values in 1 year is more significant when the results of 5 or 6 years are being compared than when results for 4 or 3 years only are in hand. The method of weighing the results is fully explained in the discussion of results as to total sugar content. Recapitulations of the detailed comparisons are presented in Table 2, total sugar; Table 3, titratable acidity; and Tables 4, 5, and 6, total astringency, tannins, and astringent nontannins. In the recapitulations the results obtained in the detailed comparisons of the various subgroups have been combined into single groups, but in the accompanying discussions they are considered separately.

TOTAL SUGAR CONTENT

The results of examination of the data for the several years with respect to the comparative total sugar content of the varieties analyzed in each year are summarized in Table 2. Such summation does not permit direct evaluation of the several years, since it contains results derived from comparison of periods of varying lengths, to which differing degrees of significance should be attached. In the case of groups analyzed for four or more years, the tendency of the crop toward attainment of high or low sugar content in any year is not adequately indicated by the number of the group having maximum or minimum values. The number of values standing next to maximum or minimum, as the case may be, also has significance as indicating the degree to which massing of values toward one end of the possible range has occurred. In the case of data covering only three years only maximum or minimum values can be considered as significant. In the comparisons which immediately follow, as well as in those made with respect to other constituents in subsequent sections, the ranking of each year has been determined by combining the number of maximum values in the 3-year groups with the number of maximum and next to maximum values in the 6-year, 5-year, and 4-year groups, and comparing the total, expressed as a percentage of the number analyzed in that year, with percentages for the other years arrived at in like manner. In the case of minimum values an identical method has been employed.

Examination of the data by the method indicated shows that in order of total sugar content 1923 stands first, with 150 out of 200 varieties, or 75 per cent, having maximum values in the 3-year group and maximum or next to maximum values in the other groups. The year 1921 is second with 44 out of 76, or 57.9 per cent; 1925 third, with 49 out of 120, or 40.8 per cent; 1922 fourth, with 64 out of 199, or 32.1 per cent; 1920 fifth, with 22 out of 69, or 31.8 per cent; and 1924 sixth, with 32 out of 190, or 16.8 per cent. That this ranking is justified is further indicated by examination of the distribution in rank of the remaining analyses. The year 1923 has very small percentages of minimum values in all the groups, and the number of next to minimum values in the 4-year, 5-year, and 6-year

groups are also small. The year 1924 has 64.5 per cent of the 3-year group, 51.2 per cent of the 4-year group, and 43.6 per cent of the 5-year group, showing minimum values for sugar. The number of next to minimum values in the 4-year and 5-year groups is also large. There is a very evident tendency toward the massing of varieties in maximum or second-place positions with respect to sugar in 1923, while 1924 shows a like massing in minimum or next to minimum positions.

TABLE 2.—*Comparative ranking of apple crop, 1920–1925, with respect to total sugar content*

Crop of—	Number of varieties compared	Number of times the crop designated ranked as specified in total sugar content					
		First (maximum)	Second	Third	Fourth	Fifth	Sixth
1920	6 years, 9	0	1	3	2	1	2
	5 years, 29	3	6	7	6	7	
	4 years, 18	3	6	5	4		
	3 years, 13	3	5	5			
1921	6 years, 9	2	1	2	2	0	2
	5 years, 33	11	10	7	3	2	
	4 years, 26	5	11	8	2		
	3 years, 8	4	0	4			
1922	6 years, 9	0	1	2	1	3	2
	5 years, 45	4	3	12	19	7	
	4 years, 81	14	26	22	19		
	3 years, 64	16	35	13			
1923	6 years, 9	5	3	0	1	0	0
	5 years, 45	22	12	6	1	4	
	4 years, 84	48	16	13	7		
	3 years, 62	44	11	7			
1924	6 years, 9	1	1	2	2	2	1
	5 years, 39	2	5	5	10	17	
	4 years, 80	7	11	21	41		
	3 years, 62	5	17	40			
1925	6 years, 9	1	2	0	1	3	2
	5 years, 34	3	10	8	7	6	
	4 years, 67	13	19	20	15		
	3 years, 10	1	5	4			

The year 1921 stands second to 1923 in percentage of varieties having high sugar content. The crop was considerably reduced in size by frosts occurring on March 29 and 30 and April 2 and 11. Abnormally high temperatures throughout March had initiated the development of fruit buds, and the result of the series of frosts was practically total destruction of the early-blooming varieties and considerable injury to the later ones. The distribution of the injury to the late-blooming varieties was somewhat unusual. Practically all the fruit on the trees of the outer rows on the southern and western sides of the orchard was killed. In the body of the orchard, damage was in many cases confined to the tops or southwest sides of the trees. On the remaining branches, damage when present was confined to the central buds of the clusters, with the result that half to three-fourths of the tree had a crop of normal quantity.

The literature contains very little definite information as to the effects of such local destruction of buds upon the composition of the crop on the fruiting portions of the tree. It was believed that some light upon this question might be obtained by making a careful survey of the orchard, estimating and noting the percentage and

distribution of the crop on the trees of each variety, and examining the analytical data for such indications as they might yield. In consequence, detailed notes upon the varieties listed for analysis were made in the orchard in June and again in September before picking began. The varieties taken for analysis were restricted to those having two-thirds or more of the tree in fruit and with 80 to 100 per cent of the normal load on the fruiting portions. For purposes of comparison, a number of varieties having half or more of the tree barren, but with a fair load on the fruiting portion, were also sampled. While it was anticipated that an effect of the larger area of barren branches might be apparent when these groups were compared, exhaustive comparisons do not show any evidence of such effect upon the composition of the fruit. This matter will be discussed more in detail in a subsequent section, but it may be stated here that the rank attained by the year 1921 in point of sugar content is attributable to the seasonal conditions during its development, not to reduction of the load of fruit on the trees by frost injury.

Of the total number of variety samples analyzed in 1921, 28.9 per cent had maximum and 28.9 per cent next to maximum sugar. Of the group of 33 fruiting in five years, 21 had highest or next to highest sugar; of the group of 26 fruiting in four years, 16 had highest or next to highest sugar. The small numbers of varieties occupying low positions in the various groups are also indicative of the very general mass tendency to attain rather high sugar content in this year.

The year 1922 ranks fourth in the number of varieties having maximum or next to maximum sugar, 32.71 per cent of the 199 varieties analyzed falling in this group. That the year ranked far below 1923 in the intensity of the climatic factors favoring large accumulations of sugar in the crop is indicated by several facts. Only 17 per cent of the 199 varieties analyzed in 1922 had maximum sugar, while 59.5 per cent of the 200 varieties analyzed in 1923 had the maximum. In 1922, 15 per cent had the next to maximum amount, while in 1923 only 21 per cent fell into this group, so that the mass tendency toward highest place is much more pronounced in 1923. Also, the totals in first place are made up largely from analyses for three years only. Of the 64 varieties in this group, 47 were analyzed only in 1922, 1923, and 1924. Of these 47 varieties, 32 had their maximum and 9 their next to maximum sugar in 1923, while 30 had their minimum and 11 their next to minimum sugar in 1924. Of the 47, 11 had maximum, 26 next to maximum, and 7 minimum in 1922. The effect of comparing 1922 with the exceptionally unfavorable year 1924 and the highly favorable year 1923 results in throwing a large number of the group into middle position. The fact that a considerable number of the varieties bore a crop of less than normal size in 1921, and that the crop of 1922 consequently followed a year of fairly vigorous vegetative growth may also contribute in some degree toward the development of higher sugar content than would have been found under identical conditions after a year of normal bearing.

With all these considerations in mind, 1922 must be ranked as decidedly inferior to 1923, in so far as conditions favoring maximum accumulation of sugar in fruits are concerned. As compared with 1921, it has a very much smaller percentage of varieties attaining

highest sugar content—17.9 as against 28.9 per cent, and also a smaller percentage in second place—15 as against 28.9 per cent. The very considerable number of varieties ranking in third and fourth place in 1922 also justifies the placing of 1921 somewhat ahead of 1922 in respect to sugar content of crop.

The year 1925 ranks third in point of number of varieties attaining high sugar content. The total number of varieties analyzed was 120. The reduction in number was due to the fact that the year was one of rather light bearing throughout the variety orchard, and a large number of varieties used in previous years either failed to set fruit or had so small a crop that samples would not have been representative. A few varieties which had crops of normal size, but which had fruited only occasionally in previous years, were not sampled because of the limited time available for the work. The 120 varieties included in the analyses in all cases had crops which approximated in quantity those borne by the same trees in previous years of the work. This year is like 1924 in that the number of varieties having maximum sugar content is small, 15 per cent, or about half the percentage found in first place in 1921. It owes its rank to the possession of 25.8 per cent in next to maximum place. Inspection of the distribution of results over the groups (Table 2) shows that the year is characterized by the absence of extremes and the massing of the results in second, third, and fourth places. It ranks third in the series of six years in point of number of varieties attaining high sugar content.

The year 1920 ranks fifth in percentage of varieties having maximum or next to maximum sugar content. Of the 69 varieties examined, 9, or 13.03 per cent, had maximum, and 13, or 18.8 per cent, next to maximum values, or 31.8 per cent of first and second place values combined. This percentage is almost identical with the 32.1 per cent of similar values found for 1922, but the fact that second-place values enter more largely into the total would rank the year as slightly below 1922 in this respect. The fact that it has considerably larger percentages of minimum values in all the groups would confirm this judgment. It is very considerably superior to 1924, since there is no such pronounced tendency toward large numbers of minimum values as is manifested in that year.

RELATION OF SUCROSE CONTENT TO TOTAL SUGAR CONTENT

The amounts of sucrose present in the fruit and the ratio borne by the sucrose content to the total sugar present show considerable variations from year to year, but there is a rather consistent tendency for sucrose and total sugar to attain maximum or minimum values together. Detailed consideration of this point is apart from the purpose of the present discussion, but it may be pointed out that in 1920, of 69 varieties analyzed, 9 had maximum total sugar, 2 had maximum sucrose; in 1921, of 76 varieties analyzed, the numbers were 22 and 20, respectively; in 1922, of 199 varieties analyzed, 34 and 35; in 1923, of 200 varieties, 119 and 122; in 1924, of 190 varieties, 15 and 21; and in 1925, of 120 varieties, 18 and 17. There is somewhat less close agreement in the occurrence of minimum values of total sugar and sucrose, but in no case are maximum or next to maximum values for one associated with minimum values for the other. It is therefore apparent that conditions which are favorable to the attainment of high total sugar content are favorable also to

the attainment of a high content of sucrose. Conditions which depress sugar storage in the fruit result also in a low content of sucrose. The relationship is a general rather than an absolute one, but it is rather consistently sustained throughout the results.

TOTAL TITRATABLE ACIDITY

Table 3 presents a recapitulation of results with respect to titratable acidity, made by the method employed in summarizing the results upon total sugars. The year 1921 leads in percentage of varieties having high acidity, with 46.0 of maximum and 21.1 per cent of next to maximum values for acid constituents, or 67.1 per cent together. The year 1920 has 56.5 per cent of high values, of which 23.2 per cent are maximum and 33.3 per cent next to maximum values; 1923 has 55.8 per cent, of which 36 per cent are maximum and 19.9 per cent next to maximum values; and 1922 has 52.7 per cent, of which 36.1 per cent are maximum and 16.5 per cent next to maximum values. These years rank so close together that assignment of relative place can be made only by considering them in some detail. Since 1923 and 1922 each has 36 per cent of maximum values, they clearly rank higher than 1920, which has 23.2 only. As 1923 has 19.9 per cent of next to maximum values as compared with 16.5 per cent of such values for 1922, 1923 apparently ranks slightly above 1922 with respect to acidity. Comparison of the numbers of minimum or next to minimum values for the two years confirms this ranking. The year 1920 ranks fourth for the reason that it has a much smaller number of maximum and a considerably larger number of next to maximum acidity values than are found in either 1922 or 1923. The differences between the three years are, however, very slight.

TABLE 3.—*Comparative ranking of apple crop, 1920–1925, with respect to acid content*

Crop of—	Number of varieties compared	Number of times the crop designated ranked as specified in acid content					
		First (maximum)	Second	Third	Fourth	Fifth	Sixth
1920	6 years, 9	1	3	3	1	1	0
	5 years, 29	8	11	5	3	2	
	4 years, 18	5	9	4	0		
	3 years, 13	2	5	6			
1921	6 years, 9	5	1	2	1	0	0
	5 years, 33	14	6	10	2	1	
	4 years, 26	12	9	2	3		
	3 years, 8	4	2	2			
1922	6 years, 9	2	0	2	4	1	0
	5 years, 45	8	13	13	9	2	
	4 years, 81	30	20	23	8		
	3 years, 64	32	20	12			
1923	6 years, 9	1	4	1	0	2	1
	5 years, 45	11	9	8	12	5	
	4 years, 84	32	26	22	4		
	3 years, 62	28	23	11			
1924	6 years, 9	0	1	1	1	3	3
	5 years, 39	4	6	7	15	7	
	4 years, 80	9	24	24	23		
	3 years, 62	7	20	35			
1925	6 years, 9	0	0	0	2	2	5
	5 years, 34	0	0	3	4	27	
	4 years, 67	1	1	14	51		
	3 years, 16	0	3	7			

The situation is decidedly otherwise in 1924, which ranks fifth in point of acid content. The year has 10.5 per cent of varieties with maximum acid, 46.3 per cent with next to maximum. There is a decided preponderance of minimum results. Of the varieties analyzed in 5 years, 56.4 per cent have minimum or next to minimum acidity; of those analyzed 4 years, 58.7 per cent take similar position; while of those analyzed 3 years only, 56.4 per cent had their minimum in 1924. In each of the groups there is the same general situation—a small number of varieties high in acidity, a somewhat larger number ranking as medium or average, and a majority with acid content at or near the minimum.

In 1925 the same tendency is shown in a much more pronounced degree. Less than 2 per cent of the varieties had maximum or next to maximum acidity, while in the groups analyzed for different periods 70 to 80 per cent of each group show minimum acidity. The mass tendency toward low acidity observable in 1924 manifests itself in extreme degree in 1925. The two years 1924 and 1925 therefore differ only in the intensity of a mass effect exactly opposite to that seen in the other years.

TANNIN AND OTHER ASTRINGENT SUBSTANCES

It is a matter of great regret that determinations of total astringency and of astringent nontannins were not made upon the freshly pressed juices in 1920 and 1921. Immediate complete chemical analysis of the juices as they were pressed was impossible in these years, as the time of the writer was largely occupied with other investigations which necessitated absence from Washington for a part of the time during which samples were being taken. The determinations made upon the fresh juices were therefore restricted to free reducing sugars, total sugars, titratable acidity, and, in part, total solids. Samples in all cases were preserved by Pasteurization, and it was planned to employ these in a study of astringent substances to be made at a later time. While it was known that such treatment would bring about some alterations in the astringent substances in solution in the juice, the writer in common with earlier workers, erred in regarding these as of minor importance. It was not until the beginning of a study of the effects of Pasteurization upon the composition of apple and grape juices, late in 1921, that the extent and importance of the alterations in astringent substances produced by Pasteurizing a fruit juice were realized.[3] These changes affect both true tannins and astringent nontannins, and are conditioned upon so many factors that determinations of these constituents made upon Pasteurized juices give no indication as to what their amounts may have been in the same juices prior to heating. These facts were discovered so late in the season of 1921 that it was not possible to make astringency determinations upon more than a small number of fresh juices in that year. Such determinations were made as a part of all analyses in subsequent years. It is believed that the data for the four years 1922–1925 are sufficient in amount and were accumulated over a period of years exhibiting a sufficiently varied range of seasonal conditions to warrant the drawing of some general conclusions.

[3] CALDWELL, J. S. THE PHYSICAL AND CHEMICAL CHANGES OCCURRING IN FRUIT JUICES AS A RESULT OF PASTEURIZATION. [Unpublished manuscript.]

The term "total astringent substances" is a broadly inclusive one, embracing all substances which reduce potassium permanganate under definite conditions. True tannins, tannin derivatives, coloring matters, and substances of highly diverse and partially unknown character are included in the determination. A second titration with potassium permanganate after precipitation and removal of the true tannins with gelatin permits a determination of the tannins by difference and an estimation of the amount of nontannins. Both are then expressed in terms of tannin by the use of a conventional factor (*6*). Both the method of determination and that of expression of the results are exceedingly unsatisfactory. It is known that the oxidation of oxidizable substances is far from complete under the usual conditions of the test (*16*), that the application of the conventional factor to the tannins of fruits gives a result which is only about 60 per cent of the true one (*23*), and that in the case of certain red wines the use of the conventional factor to express nontannins gives a result which is only 30 per cent of the true weight of these substances (*29*). In spite of these defects, no method which is at once more accurate and equally easy of application has been developed to replace the modified Loewenthal procedure. That method has consequently been employed, as the results obtained by its use have value for purposes of comparison despite their lack of quantitative accuracy.

If the sum total of astringent materials is affected in a definite manner by climatic conditions it is a matter of some practical importance, since the palatability of a fruit or the beverage quality of a juice made therefrom depends upon the relative proportions of sugar, acids, and astringent materials present. In determining the effect upon the palate, all the astringent substances present play a part, no matter what their origin or chemical relationships. If climatic conditions exercise such a decisive effect upon some one or more of these constituents as to influence the sum total in a definite direction, the palatability of the juice will be affected. It is as important from the practical point of view to know whether a given set of climatic conditions tends to increase or decrease total astringency as it is to know their effect upon sugar and acid content, since an alteration in the amount of any one of these constituents modifies the ratios between them and alters their collective effect upon the palate. That climatic conditions have such a definite effect upon total astringency in the case of the grape has been shown by Caldwell (*11*).

Comparison of the summaries on total astringency, tannin, and astringent nontannins in Tables 4, 5, and 6 show no evidence that total astringency is definitely affected as regards its absolute amount by seasonal conditions. In 83 varieties on which determinations were made annually in 1922–1925 (Table 4) there is no indication of a mass tendency toward high or low total astringency in any year. In the group of 74 varieties analyzed only in the three years 1922–1924 there appears to be some tendency toward high astringency in 1923 and toward low in 1924, but 1922 has larger numbers of maximum and minimum results than of second-place results. The various smaller groups also show no evidence of concentration of high or low values in any one year. It is evident that total astringency does not display mass behavior in its variations in absolute amount from year to year and that these variations can not be directly related to differences in the seasonal conditions of the year concerned.

TABLE 4.—*Comparative ranking of apple crop, 1922–1925, with respect to total astringency*

Crop of—	Years analyzed	Number of varieties	Number of times the crop designated ranked as specified in total astringency			
			First (maximum)	Second	Third	Fourth
1922	4 years	83	22	21	15	25
	3 years (1922, 1923, 1924)	74	27	20	27	
	3 years (1922, 1923, 1925)	14	6	1	7	
	3 years (1922, 1924, 1925)	7	4	2	1	
1923	4 years	83	22	21	21	19
	3 years (1922, 1923, 1924)	74	30	28	16	
	3 years (1922, 1923, 1925)	14	3	7	4	
	3 years (1923, 1924, 1925)	10	5	3	2	
1924	4 years	83	19	20	24	20
	3 years (1922, 1923, 1924)	74	17	26	31	
	3 years (1922, 1924, 1925)	7	1	4	2	
	3 years (1923, 1924, 1925)	10	0	5	5	
1925	4 years	83	20	22	23	18
	3 years (1922, 1923, 1925)	14	5	9	0	
	3 years (1922, 1924, 1925)	7	2	2	3	
	3 years (1923, 1924, 1925)	10	5	3	2	

TRUE TANNINS

A somewhat unexpected fact in respect to the portion of the astringent material which is precipitable by addition of gelatin-salt solution is that in practically all varieties there is a very wide variation from year to year in the amounts found at like stages of maturity. In many cases the variation exceeds 100 per cent. These extremely wide variations occur not only in highly astringent crab varieties such as Amère du Surville, Entz, Hyslop, Julian de Paulmier, Soulard Crab, and Red Siberian, but also in apple varieties such as Hubbardston, Northwestern Greening, Nero, Mother, Shoemaker, and Rome Beauty. In a much smaller group of crab varieties which also contains a few rather highly astringent fruits, such as Florence, Lyman Prolific, and Yellow Siberian, with a large number of apples such as Allington Pippin, Winter Banana, Fameuse, Sutton, Cox No. 13, Roxbury Russet, and White Pearmain, the variations in true tannins are of relatively smaller magnitude, from 10 to 50 per cent. The number showing this degree of constancy is small as compared with the number of those displaying a wide range.

As indicated in Table 5, the data available upon true tannins are derived from a group of 83 varieties fruiting annually in the four years 1922–1925, a group of 74 fruiting in the three years 1922–1924 but having no crop or else crops too small to be included in the analyses in 1925, and three small groups each of which fruited in three of the four years.

Combining the numbers of maximum values in the 3-year groups with the maximum and next to maximum values of the 4-year group, the percentages in the several years are as follows: For 1923, 53.5; for 1925, 42.1; for 1924, 36.2; and for 1922, 35.3 per cent. This would rank the years in the order named in point of astringent nontannin content but with no significant difference between 1924 and 1922. Considering the data in greater detail, it is found that of the group of 83 varieties analyzed in four years,

1922, 1923, and 1925 each have 22 with maximum values, while 1924 has 17. When maximum and next to maximum values are combined, 1923 has 52 as against 39 for 1925, 38 for 1924, and 37 for 1922. The results for the group of 74 varieties analyzed in the years 1922–1924 rank these years in the order 1923 first, 1924 second, and 1922 third. Comparison of the numbers of minimum values give the three years the same rank. The numbers in the small groups which fruited in 1925 but failed to fruit in one of the other years are too small to be of much significance; they indicate that the year was one of rather low true tannin content.

TABLE 5.—*Comparative ranking of apple crop, 1922–1925, with respect to true tannin*

Crop of—	Number of varieties compared	Number of times the crop designated ranked as specified in true tannins			
		First (maximum)	Second	Third	Fourth
1922	4 years, 83	22	15	14	32
	3 years (1922, 1923, 1924), 74	16	23	35	
	3 years (1922, 1923, 1925), 14	7	1	6	
	3 years (1922, 1924, 1925), 7	3	1	3	
1923	4 years, 83	22	30	17	14
	3 years (1922, 1923, 1924), 74	38	19	17	
	3 years (1922, 1923, 1925), 14	4	2	8	
	3 years (1923, 1924, 1925), 10	3	4	3	
1924	4 years, 83	17	21	23	22
	3 years (1922, 1923, 1924), 74	20	32	22	
	3 years (1923, 1924, 1925), 10	3	4	3	
	3 years (1922, 1924, 1925), 7	2	3	2	
1925	4 years, 83	22	17	30	14
	3 years (1923, 1924, 1925), 10	4	2	4	
	3 years (1922, 1924, 1925), 7	2	3	2	
	3 years (1922, 1923, 1925), 14	3	11	0	

These comparisons appear to justify the conclusion that 1923 ranked distinctly above any of the other years for which data are available in respect to true tannins present in the crop. The remaining years show no outstanding differences which entitle one to be ranked higher than another. There is no year showing a distinct minimum, and the evidence scarcely justifies one in going further than to say that 1923 had a distinctly higher content of true tannins in the crop than was found to be present in the other years. If the tannin content of the crop as a whole is affected by climatic conditions, the effect is very much less pronounced in character than that exerted upon other constituents.

ASTRINGENT NONTANNINS

In the group of 83 varieties analyzed in the four years 1922 to 1925 (Table 6), 1924 has the largest percentage of maximum astringent nontannins, namely 31.3 per cent, but is rather closely followed by 1922 with 28.9 per cent. The years 1925 and 1923 rank considerably lower, with percentages of 20.4 and 19.2 maximum values, respectively. Combination of maximum and second-place values for each of the years would rank them in the order 1924, 1922, 1925, and 1923. The results with the group of 74 varieties analyzed in 1922 to 1924 only

are quite different, since 1922 has 52.7 per cent maximum values as compared with 33.8 per cent for 1923 and 14.8 per cent for 1924. Since the results with the 4-year and the 3-year groups are quite out of agreement, no conclusion can be drawn other than that there is evidently no consistent mass tendency toward maximum or minimum astringent nontannin content in any of the several years considered.

TABLE 6.—*Comparative ranking of apple crop, 1922–1925, with respect to astringent nontannins*

Crop of—	Number of varieties compared	Number of times the crop designated ranked as specified in astringent nontannins			
		First (maximum)	Second	Third	Fourth
1922	4 years, 83	24	17	13	29
	3 years (1922, 1923, 1924), 74	39	12	23	
	3 years (1922, 1923, 1925), 14	7	2	5	
	3 years (1922, 1924, 1925), 7	4	1	2	
1923	4 years, 83	16	21	27	19
	3 years (1922, 1923, 1924), 74	25	35	14	
	3 years (1922, 1923, 1925), 14	2	6	6	
	3 years (1923, 1924, 1925), 10	5	4	1	
1924	4 years, 83	26	21	19	17
	3 years (1922, 1923, 1924), 74	11	28	35	
	3 years (1923, 1924, 1925), 10	2	3	5	
	3 years (1922, 1924, 1925), 7	2	3	2	
1925	4 years, 83	17	24	25	17
	3 years (1923, 1924, 1925), 10	3	3	4	
	3 years (1922, 1924, 1925), 7	1	3	3	
	3 years (1922, 1923, 1925), 14	5	6	3	

It may be pointed out that the rankings of the years with respect to true tannins and astringent nontannins show no consistent relations. The year 1923 had a high content of true tannins, but this is not clearly associated with a low content of nontannins, or the reverse. The two constituents appear to fluctuate independently, with no outstanding mass tendencies which could be attributed to the effect of varying seasonal conditions apparent in the case of either. In consequence, total astringency, which is the sum of the two, shows no indication of mass behavior in its variation in absolute amount from year to year.

ACID-ASTRINGENCY-SUGAR RATIO

As has been pointed out in a preceding section, palatability of a fruit or fruit juice depends upon the relative proportion of acids, astringent materials, and sugar simultaneously presented to the nerve endings of taste. If the proportion between amounts of these constituents is kept constant, their absolute amounts may be varied over a considerable range without producing any effect discernible by the sense of taste. On the other hand, very slight differences in the proportion of the different constituents are readily perceived, as is shown by the fact that our judgments that one juice is more astringent but less sweet than another, or that one fruit is sweeter than another, are based upon small chemical differences. The error of such judgments results chiefly from the fact that higher or lower sugar con-

tent is frequently confused with decreased or increased acid content. In so far as our judgments of dessert quality in fruit are based upon characters measurable by chemical analysis, they are determined by the ratio between acid, tannin, and sugar present in the flesh. In the case of a juice, this ratio, plus the effects of the minute amounts of volatile substances which give characteristic individual aroma and flavor, determines our verdict as to quality, since considerations as to physical characters, such as texture and crispness of flesh, do not enter as they do in the case of a fruit.

For this reason the proportion borne by the sugars, astringent materials, and acids one to another is an exceedingly important factor in determining palatability whether in a fruit or in a fruit juice. It follows that it is a matter of great practical importance to ascertain the amount of annual variation in this ratio in apple varieties and to learn whether any causal relations exist between climatic conditions and such variations.

While the amount of data here available is not such as to warrant dogmatic conclusions, it may give some indications as to what may be expected as a result of further investigation.

TABLE 7.—*Acid-astringency-sugar ratios for varieties of apples analyzed in years shown*

Variety	1922	1923	1924	1925
Four years' analyses:				
Abernathy	1:0.22 :21.7	1:0.42 :27.6	1:0.24 : 29.0	1:0.39 : 34.5
Algérienne	1: .72 :26.1	1:1.13 :52.2	1: .83 : 40.1	1:1.04 : 79.6
Allington Pippin	1: .12 :12.2	1: .22 :18.2	1: .14 : 13.5	1: .31 : 27.2
Amère du Surville	1: .82 :24.2	1:3.49 :45.8	1:2.95 : 74.2	1:2.69 : 73.2
Akin	1: .25 :24.2	1: .24 :32.3	1: .21 : 23.9	1: .25 : 35.9
Arctic	1: .26 :33.7	1: .27 :22.9	1: .31 : 19.2	1: .35 : 29.1
Babbitt	1: .092: 8.4	1: .084: 9.3	1: .106: 9.5	1: .11 : 11.9
Baker	1: .14 :20.2	1: .20 :31.7	1: .20 : 21.9	1: .25 : 28.4
Baldwin	1: .15 :18.4	1: .21 :23.5	1: .29 : 26.7	1: .22 : 24.0
Ben Hur	1: .21 :28.0	1: .21 :31.1	1: .21 : 36.3	1: .42 : 52.7
Bennet	1: .20 :29.0	1: .23 :33.9	1: .34 : 38.7	1: .31 : 32.7
Bethlehemite	1: .22 :35.8	1: .24 :30.7	1: .29 : 31.6	1: .63 : 66.1
Black Ben	1: .25 :15.8	1: .24 :22.8	1: .25 : 24.8	1: .21 : 20.6
Bughorn	1: .31 :20.1	1: .19 :20.9	1: .23 : 18.9	1: .37 : 28.4
Carson	1: .21 :16.6	1: .11 :15.9	1: .071: 12.1	1: .11 : 20.2
Celestia	1: .16 :17.8	1: .11 :19.8	1: .18 : 29.8	1: .22 : 31.1
Collins	1: .13 :13.3	1: .14 :18.7	1: .11 : 18.2	1: .28 : 27.9
Cox No. 13	1: .099:21.6	1: .12 :20.5	1: .13 : 26.1	1: .21 : 33.7
Dixon	1: .23 :29.0	1: .12 :16.2	1: .095: 18.6	1: .17 : 23.9
Domine	1: .22 :23.3	1: .21 :25.2	1: .143: 22.2	1: .247: 31.9
Pyrus angustifolia	1: .29 : 1.39	1: .46 : 2.76	1: .27 : 1.77	1: .39 : 2.02
Flory	1: .12 :10.3	1: .13 :13.5	1: .22 : 15.3	1: .16 : 11.1
Greenville	1: .25 :23.1	1: .12 :16.2	1: .14 : 15.2	1: .24 : 24.9
Haas	1: .11 :10.8	1: .19 :21.1	1: .20 : 14.8	1: .27 : 22.7
Hagloe Crab	1: .123: 6.78	1: .19 :17.1	1: .21 : 14.3	1: .21 : 17.0
Hilaire	1: .18 :13.5	1: .12 :13.3	1: .17 : 13.3	1: .21 : 23.4
Hoover	1: .13 :15.9	1: .14 :15.9	1: .22 : 15.9	1: .21 : 24.8
Huntsman	1: .35 :38.1	1: .18 :25.9	1: .165: 21.6	1: .33 : 35.1
Hyslop	1: .56 :15.4	1: .61 :22.0	1: .65 : 16.8	1: .61 : 26.1
Hort. No. 4941	1: .81 :71.0	1: .43 :44.7	1: .79 : 85.6	1: .85 : 80.7
Indian	1: .30 :21.8	1: .18 :18.7	1: .40 : 26.3	1: .40 : 30.0
Jefferis	1: .18 :10.5	1: .18 :20.8	1: .30 : 33.0	1: .20 : 23.1
Keeper	1: .11 :21.1	1: .13 :28.6	1: .12 : 24.0	1: .13 : 26.4
Kentucky Sweet	1: .74 :36.7	1:1.09 :65.0	1: .82 : 65.2	1: .79 : 59.6
Klickitat	1: .14 :19.2	1: .20 :35.6	1: .20 : 24.7	1: .29 : 35.4
Kooroochiang	1: .072:10.3	1: .96 :11.7	1: .12 : 11.5	1: .18 : 21.1
Magg	1: .117:19.4	1: .24 :22.3	1: .21 : 15.0	1: .27 : 26.5
Magog	1: .20 :25.6	1: .15 :18.8	1: .30 : 14.1	1: .18 : 19.4
Monmouth	1: .12 :17.6	1: .22 :27.9	1: .23 : 19.4	1: .33 : 36.9
Mann	1: .19 :20.6	1: .16 :19.7	1: .19 : 17.9	1: .32 : 32.1
Martin	1: .29 :39.3	1: .38 :61.3	1: .27 : 45.1	1: .53 : 55.0
McAfee	1: .21 :19.9	1: .30 :30.4	1: .30 : 25.5	1: .51 : 43.5
McIntosh	1: .17 :16.6	1: .19 :17.5	1: .17 : 24.8	1: .28 : 25.4
McMahon	1: .14 : 7.6	1: .085: 8.1	1: .12 : 10.2	1: .17 : 17.2
Menagere	1: .23 :25.4	1: .25 :31.9	1: .18 : 25.8	1: .43 : 41.5
Missouri	1: .24 :22.2	1: .13 :17.3	1: .16 : 20.3	1: .28 : 26.8
Mother	1: .30 :31.8	1: .26 :26.8	1: .25 : 23.2	1: .46 : 45.9

TABLE 7.—*Acid-astringency-sugar ratios for varieties of apples analyzed in years shown*—Continued

Variety	1922	1923	1924	1925
Four years' analyses—Continued.				
Nero	1:0.23 :33.1	1:0.36 :39.2	1:0.44 : 36.5	1:0.45 : 39.0
Newtown Spitzenburg	1: .15 :19.9	1: .23 :30.8	1: .21 : 24.3	1: .28 : 36.6
Nickajack	1: .19 :21.4	1: .28 :41.7	1: .242: 37.1	1: .52 : 42.9
Ohio Pippin	1: .21 :20.4	1: .27 :23.4	1: .25 : 29.8	1: .23 : 24.5
Pawpaw	1: .19 :17.9	1: .12 :14.4	1: .15 : 14.6	1: .24 : 25.1
Peron	1: .18 :10.2	1: .21 :17.6	1: .27 : 18.5	1: .45 : 30.7
Rabum	1: .47 :51.1	1: .27 :32.2	1: .35 : 32.6	1: .28 : 28.6
Ralls	1: .13 :18.6	1: .17 :27.8	1: .18 : 29.6	1: .33 : 39.4
Rome Beauty	1: .24 :28.9	1: .18 :30.9	1: .31 : 31.1	1: .36 : 31.9
Ronk	1: .22 :19.3	1: .12 :18.1	1: .19 : 16.2	1: .19 : 21.2
Salome	1: .071:15.9	1: .12 :19.8	1: .12 : 13.7	1: .192: 25.3
Scott Winter	1: .08 : 9.8	1: .11 :10.9	1: .105: 16.9	1: .15 : 13.3
Shackleford	1: .13 :18.1	1: .19 :24.2	1: .23 : 21.8	1: .41 : 42.0
Shoemaker	1: .187:13.7	1: .14 :11.5	1: .41 : 26.4	1: .29 : 25.4
Shone	1: .095:22.8	1: .12 :21.2	1: .14 : 22.0	1: .17 : 30.7
Smokehouse	1: .12 :19.3	1: .21 :23.4	1: .23 : 20.0	1: .32 : 31.6
Swaar	1: .18 :19.7	1: .14 :21.7	1: .16 : 16.6	1: .16 : 28.7
Sweet Orange	1: .64 :41.6	1: .22 :25.3	1: .51 : 77.0	1: .67 : 61.2
Sutton	1: .23 :22.2	1: .31 :32.2	1: .16 : 23.3	1: .30 : 32.7
Tompkins King	1: .18 :19.2	1: .27 :31.0	1: .24 : 23.6	1: .31 : 32.3
Transcendent	1: .31 : 8.8	1: .48 :15.2	1: .76 : 21.1	1: .27 : 13.0
Vandevere	1: .13 :19.7	1: .21 :23.7	1: .19 : 21.9	1: .22 : 33.8
Vanderpool	1: .22 :33.5	1: .27 :24.0	1: .32 : 37.6	1: .49 : 44.5
Victoria Sweet	1: .20 :25.5	1: .51 :43.2	1: .66 : 63.6	1: .97 : 89.3
Walbridge	1: .15 :14.1	1: .19 :24.9	1: .18 : 15.4	1: .23 : 19.4
Wallace Howard	1: .41 :32.0	1: .30 :31.6	1: .24 : 22.3	1: .36 : 38.9
Weaver	1: .64 :54.4	1: .52 :52.9	1: .52 : 56.2	1: .72 : 66.0
Wells	1: .19 :24.2	1: .20 :26.3	1: .091: 13.5	1: .18 : 20.4
Westfield	1: .24 :22.7	1: .22 :26.4	1: .19 : 23.3	1: .28 : 29.3
Wingate	1: .17 :10.7	1: .21 :17.0	1: .24 : 19.7	1: .21 : 19.0
Winter Paradise	1: .127:89.1	1: .108:92.2	1: .156: 88.0	1: .176:124.0
Wolf River	1: .097: 9.5	1: .13 :13.0	1: .13 : 13.6	1: .13 : 15.5
Yellow Transparent	1: .28 :11.6	1: .16 : 6.73	1: .31 : 13.8	1: .15 : 15.7
Yopp	1: .28 :32.0	1: .25 :33.4	1: .34 : 23.9	1: .33 : 32.2
Three years' analyses:				
Alton	1: .121:16.4	1: .126:23.5	1: .085: 15.0	----------
Arnold	1: .16 :20.5	1: .15 :18.6	1: .20 : 22.0	----------
Baltimore	1: .50 :42.4	1: .23 :33.7	1: .39 : 34.3	----------
Barry	1: .10 : 6.2	1: .13 : 9.6	1: .12 : 9.9	----------
Black Annette	1: .24 :25.0	1: .17 :21.6	1: .32 : 29.9	----------
Blenheim	1: .10 :18.1	1: .167:16.2	1: .16 : 19.0	----------
Bolken	1: .083:12.6	1: .12 :14.9	1: .081: 12.0	----------
Brackett	1: .34 :29.4	1: .23 :25.4	1: .27 : 26.2	----------
Brown	1: .205:21.6	1: .19 :23.9	1: .17 : 18.2	----------
Buckingham	1: .10 :22.5	1: .22 :21.1	1: .22 : 20.8	----------
Buckskin	1: .15 :17.3	1: .17 :20.3	1: .26 : 18.0	----------
Canada Reinette	1: .19 :18.5	1: .12 :12.0	1: .21 : 15.7	----------
Clayton	1: .31 :35.7	1: .14 :16.3	1: .30 : 29.3	----------
Colvert	1: .34 :44.5	1: .35 :36.4	1: .28 : 26.8	----------
Cotter	1: .12 :19.2	1: .13 :22.8	1: .20 : 21.7	----------
Covert	1: .20 :14.1	1: .34 :21.7	1: .22 : 18.8	----------
Cox No. 11	1: .15 :15.8	1: .078: 9.6	1: .06 : 11.8	----------
Cross	1: .29 :17.5	1: .43 :31.3	1: .30 : 21.7	----------
Daniel	1: .21 :19.1	1: .22 :23.6	1: .28 : 35.5	----------
Doctor	1: .069:15.4	1: .16 :22.4	1: .11 : 18.9	----------
Dudley	1: .12 : 8.5	1: .16 :10.7	1: .14 : 14.0	----------
Early Richmond	1: .10 : 9.98	1: .076: 6.55	1: .088: 7.8	----------
Early Ripe	1: .17 :10.5	1: .117:11.0	1: .13 : 9.02	----------
Entz	1: .31 : 8.7	1: .20 : 5.7	1: .30 : 6.7	----------
Evening Party	1: .276:30.3	1: .46 :52.1	1: .35 : 31.9	----------
Fallawater	1: .51 :41.8	1: .18 :28.7	1: .32 : 38.1	----------
Family	1: .092: 9.43	1: .104:13.8	1: .102: 13.5	----------
Golden Pippin	1: .15 :13.4	1: .16 :16.7	1: .28 : 25.5	----------
Golden Russet	1: .18 :25.9	1: .16 :21.4	1: .18 : 23.4	----------
Granny Smith	1: .14 :21.2	1: .18 :19.7	1: .16 : 15.8	----------
Grosh	1: .15 :34.1	1: .25 :25.2	1: .20 : 20.0	----------
Heidemeyer	1: .175:19.4	1: .24 :22.9	1: .24 : 20.8	----------
Henry Clay	1: .15 : 7.8	1: .205:14.9	1: .28 : 17.6	----------
Hogg	1: .13 : 6.7	1: .068: 6.08	1: .11 : 9.4	----------
Indiana Favorite	1: .23 :27.7	1: .23 :39.0	1: .17 : 32.7	----------
Jersey Sweet	1: .86 :60.3	1:1.16 :88.0	1:1.06 :128.0	----------
Lawver	1: .13 :18.0	1: .13 :16.1	1: .25 : 20.0	----------
Lou	1: .094: 8.9	1: .06 : 5.2	1: .14 : 10.6	----------
Melo Gelato	1: .30 :37.1	1: .60 :49.3	1: .45 : 46.0	----------
Morris Red	1: .27 :39.5	1: .21 :26.5	1: .47 : 42.1	----------
Muster	1: .34 :30.2	1: .33 :28.6	1: .67 : 47.6	----------
Oakland	1: .31 :41.1	1: .36 :43.1	1: .21 : 29.6	----------
Ortley	1: .12 :17.7	1: .11 :15.3	1: .178: 24.8	----------
Ozone	1: .364:30.9	1: .17 :23.6	1: .17 : 18.3	----------
Pifer	1: .27 :32.0	1: .25 :31.4	1: .34 : 39.3	----------
Piper	1: .28 :18.3	1: .37 :15.2	1: .38 : 19.2	----------

TABLE 7.—*Acid-astringency-sugar ratios for varieties of apples analyzed in years shown*—Continued

Variety	1922	1923	1924	1925
Three years' analyses—Continued.				
Primate	1:0.27 :20.3	1:0.16 :11.1	1:0.053: 57.0	
Rebel	1: .33 :41.8	1: .16 :30.0	1: .23 : 29.7	
Red June	1: .28 :14.2	1: .20 :13.1	1: .33 : 28.4	
Red Siberian	1: .39 : 9.7	1: .703:13.8	1: .90: 15.9	
Reynard	1: .11 :14.5	1: .17 :17.5	1: .18 : 21.8	
Ruby Gem	1: .21 :10.7	1: .25 :16.1	1: .293: 21.2	
Sierra Beauty	1: .08 :17.6	1: .115:18.8	1: .11 : 14.1	
Smith Cider	1: .22 :21.2	1: .25 :26.3	1: .30 : 28.9	
Spencer Seedling	1: .307:35.5	1: .48 :46.4	1: .41 : 43.4	
Springdale	1: .66 :52.7	1: .27 :22.8	1: .39 : 36.1	
Stanard	1: .18 :17.3	1: .31 :25.3	1: .30 : 22.3	
Stark	1: .15 :25.7	1: .20 :28.7	1: .30 : 32.1	
Starkey	1: .18 :19.7	1: .21 :21.7	1: .21 : 25.1	
Stinson	1: .14 :15.5	1: .14 :16.2	1: .30 : 29.4	
Sweet Romanite	1: .55 :75.2	1: .33 :38.4	1: .69 : 81.6	
Terry	1: .14 :13.4	1: .16 :16.2	1: .18 : 18.1	
Townsend	1: .15 :12.3	1: .185:22.6	1: .32 : 39.3	
Trader	1: .21 :12.3	1: .39 :25.5	1: .14 : 12.4	
Trumbull	1: .87 :51.2	1: .77 :58.5	1: .94 : 74.3	
Utter	1: .17 :16.3	1: .18 :20.7	1: .36 : 28.0	
Wealthy	1: .12 :12.0	1: .13 :16.3	1: .17 : 13.7	
White Doctor	1: .14 :12.5	1: .16 :22.4	1: .14 : 13.0	
White Pearmain	1: .167:22.4	1: .16 :23.4	1: .177: 19.3	
White Pippin	1: .13 :21.1	1: .21 :24.2	1: .16 : 16.9	
Willow	1: .11 :12.9	1: .16 :19.4	1: .18 : 17.8	
Wilson June	1: .20 :15.3	1: .25 :21.1	1: .22 : 24.1	
Wolseley	1: .14 :13.7	1: .13 :15.3	1: .007: 11.1	
Winter Smokehouse	1: .31 :31.5	1: .209:21	1: .22 : 18.6	
Yellow Siberian	1: .38 :10.8	1: .34 :11.09	1: .63 : 18.5	
York Imperial	1: .16 :25.0	1: .16 :26.7	1: .11 : 20.7	

In Table 7 the ratios of acid to total astringency and sugar have been tabulated for all varieties which fruited annually in the three years 1922–1924 or in the four years 1922 to 1925. In stating these ratios titratable acidity is taken as unity, and the figures for total astringency and total acidity are quotients obtained by dividing the percentages of each by the titratable acidity. Since in the case of any given variety for a given year the acidity for the year is always taken as unity, and its amount varies from year to year, the ratios for successive years express only the relations existing between these constituents and do not tell anything about the absolute amounts of any of them. This is only another way of saying that the ratio for any given variety and year gives a collective expression of the character of the sample as a whole. In so far as such an expression can be derived from the results of chemical analysis, it states the effect which such a mixture would produce upon the organs of taste. Such effects are not quantitative but comparative and center around the acid content.

An example or two will make the idea clear. The ratios for Baker indicate at a glance that the 1923 and 1925 juices were relatively more astringent and sweeter, and the 1924 juice more astringent, than that of 1922. The ratios for Nero indicate that the 1924 and 1925 juices were very nearly identical, but were more astringent and less acid than that of 1922, with 1923 intermediate in astringency. Akin is quite constant in its acid-astringency ratio, but the 1923 and 1925 juices, which were nearly identical, were relatively much sweeter than those of 1922 and 1924. The juice of Bughorn was closely similar in the first three years, while the juice of 1925 was decidedly more astringent and sweeter.

Since sugars, acidity, and the two classes of astringent materials are variables which fluctuate from year to year with a considerable degree of independence, it is to be expected that the ratios for successive years will show a fairly wide range. This is the case. Close ratios, such as are seen in Arnold, Baldwin, Brackett, Rome Beauty, Yopp, or Westfield, are rare, since they can occur only when the variety has very nearly the same composition from year to year or when all three constituents vary together in the same direction and to nearly the same degree. On the other hand, very wide ratios, such as occur in Jefferis, Martin, Sweet Orange, Algerienne, Victoria Sweet, Jersey Sweet, Springdale, and Red Siberian, may have any one of several explanations. If the ratios are in fairly close agreement except for one year, which has a widely different ratio, as in Springdale, possibility of error in sampling or in analysis is indicated. If the ratios fluctuate widely from year to year, it may indicate that the variety is far out of its natural environment and is especially responsive to variations in seasonal conditions. This may be the case in Sweet Orange, Martin, Algérienne, Victoria Sweet, and Jersey Sweet.

If the primary purpose of the acid-astringency-sugar ratio be kept clearly in mind and is considered as giving a conception not of quantitative chemical composition but of the collective effect of a juice upon the palate, the data presented in Table 7 has practical value as well as scientific interest.

ASTRINGENCY-SUGAR RATIO

It became evident early in this work that the juices of the group of apples subjected to analysis varied as a whole in their astringency to taste from year to year; that is to say, the juices of large numbers of varieties were apparently more astringent in one year than in another. The tabulation of the results for total astringency in Table 4 has shown that there was no general massing of large numbers of maximum or minimum values for total astringency content in any year, hence the observed differences to taste were not due to differences in absolute amounts of astringent substances present. Further examination of the data indicates that total astringency is the sum of two independently fluctuating variables, neither of which is directly affected by seasonal conditions. The absolute amounts of materials collectively termed "total astringents" therefore can not be directly influenced by seasonal conditions. The ratio borne by astringent materials to sugars present, which may be termed the "relative astringency" of the juice, does not depend upon the absolute amount of astringent materials present, but upon the ratio borne by this quantity to the total sugar present. This ratio will be affected by variation in amount of either component from year to year. It has been shown that the total sugar content of the crop displays definite mass tendencies toward high or low values from year to year, and examination of the data should indicate whether the annual variations in sugar content result in definite mass variations in the astringency-sugar ratio from year to year.

In order to obtain information upon this point, astringency-sugar ratios have been calculated for all the varieties for which data upon three or four successive crops were available. The method employed is that of division of the total sugar content of the variety in each year by its total astringent content. This gives a series of numbers

which express the relative astringency of the juice of the variety in the several years, the smallest quotient indicating highest content of astringents with relation to sugar. The results of application of this method of treatment to the available data are summarized in Table 8. In the group of 81 varieties analyzed in the four years 1922–1925, inclusive, 1924 had a much larger number showing maximum relative astringency than any other year, followed in order by 1922, 1925, and 1923. In the 77 varieties analyzed only in 1922–1924, 1922 and 1924 have 30 and 29 varieties showing maximum relative astringency, respectively, while 1923 has 18 only. Combination of the results for the two groups indicates that 1923 was decidedly lower in relative astringency than any other year. The year 1924 would appear to rank highest, rather closely followed by 1922. The position of 1925 is rather indefinite, the 4-year group has a large number of varieties showing next to maximum astringency in that year, but it probably ranks slightly below 1922. The order of the four years with respect to relative astringency is therefore 1924, 1922, 1925, and 1923.

TABLE 8.—*Comparative ranking of apple crop, 1922–1925, with respect to relative astringency content*

Year	Number of years compared	Number of varieties	Number of varieties ranking as specified in relative astringency			
			First	Second	Third	Fourth
1922	4	81	23	21	17	20
	3	77	30	19	28	
1923	4	81	7	17	31	26
	3	77	18	31	28	
1924	4	81	33	14	15	19
	3	77	29	27	21	
1925	4	81	18	30	17	16

The ranking of the various years with respect to relative astringency does not follow that found for total astringency, for an obvious reason. Relative astringency depends for its position in any year upon two factors, the absolute amount of astringent materials and the absolute amount of sugar present. Any factor which depresses sugar content thereby increases the relative astringency; any factor which increases sugar content acts in the opposite direction upon relative astringency. Any factor increasing or decreasing the absolute amount of any astringent material will of course affect the relative total in the same direction. The year 1924 was the year of the series marked by minimum sugar content and next to minimum acid content. It had a large percentage of maximum nontannins. The relative astringency is high because sugars are low and nontannins high. In 1923, the year of maximum sugar and next to maximum acidity, true tannins were higher than in any other year of the series, but relative astringency is low despite this fact. The intermediate results tend to follow the nontannins. It is clear that seasonal conditions which are favorable to the development of high sugar content tend to depress relative astringency to a low level, and,

conversely, seasonal conditions which depress the storage of carbohydrates in the fruit favor the development of a high level of relative astringency. Years of less pronounced seasonal conditions are intermediate in their results.

This differs in detail but not in general effect from the situation found in grapes. In a large group of grape varieties, maximum sugar content was associated in a majority of cases with minimum total astringency, while minimum sugar content was correlated with maximum total astringency (*11*). In most varieties of grapes true tannins make up only a small portion of the total astringency, so that the total astringency follows the nontannins irrespective of the independent variation of the true tannins. In apples true tannins make up so large a portion of the total astringent substances that their independent fluctuations affect total astringency, and consequently its absolute amount does not rigidly follow the astringent nontannins. Nevertheless these substances play the dominant rôle in determining relative astringency; that is, in determining the relation of the sum total of astringent substances to total sugars and titratable acidity.

CLIMATIC CONDITIONS AT WASHINGTON, D. C., 1918–1925

The location of the apple variety collection of the Office of Horticulture at the Arlington Experiment Farm, within 2½ miles of the Washington station of the United States Weather Bureau, makes the detailed records of that station available for the purposes of this study. The data presented in the Monthly Meteorological Summary, Form 1030, for Washington (*31*), and in Climatological Data, Virginia Section, for the years 1917–1925 (*32*), afford material for a rather complete statement of the seasonal conditions under which the successive crops were grown, and consequently make possible somewhat detailed comparisons of the various years of the period with one another and with the "normal" or 50-year average in so far as certain factors are concerned. These factors are rainfall, sunshine, and temperature, for each of which a daily record is available.

It is of course obvious that comparisons of year with year which are limited to consideration of the factors just named can present only broad outline sketches of the years concerned. For any attempt at quantitative estimation of the conditions under which plants are living in the open, continuous records of soil and atmospheric moisture, wind movement, soil temperature, solar intensity, and rate of evaporation must be available. By reason of their nature these factors must be measured in the immediate vicinity of the plants studied. No such measurements have been made in the present work. While most of these unmeasured factors are determined as regards their nature and amount by the factors of rainfall, sunshine, and temperature, this is not the case for all of them. The measurements of conditions are therefore incomplete, and any comparisons between years are necessarily qualitative, not quantitative, in character.

In the discussion which follows, the data upon temperature, sunshine, and precipitation for the years 1918 to 1925 are first presented as summary statements for the various years, each accompa-

nied by a graph of conventional type in which the data for the calendar year are compared with the values for the "normal" or 50-year average. (See figs. 1–8.) In a subsequent section the data have been rearranged in such a way as to bring the results into more direct relation to the activities of plants by replacing the division into calendar years by a division into crop years beginning October 1 and ending September 30. The data upon each of the three factors—temperature, sunshine, and rainfall—for the entire period are assembled in graphs (fig. 9, rainfall; fig. 10, sunshine; fig. 11, temperature), to facilitate comparison of individual years with one another and with the normal with respect to that factor. In another graph (fig. 12) all the data for the three factors are brought together in summary. Incidental reference to the graphs presenting the data on this basis will be made in discussing the records for individual years, but a detailed statement of the methods adopted in the rearrangement and of the reasons therefor will be postponed until comparison of the various crop years is begun.

Climatological data for the years 1918 and 1919 are presented as giving an idea of conditions preceding the experimental period.

CLIMATIC CONDITIONS IN 1918

The winter of 1917–18 was characterized by unusual cold in November, December, and January, the mean temperatures for the three months falling below the normal by 2.2°, 8.2°, and 9.3° F., respectively. February and March were warmer than usual, the daily excess in March amounting to 6.3° and being associated with precipitation and sunshine considerably greater than normal. Clear weather and temperatures below freezing in the last week of March checked plant growth and prevented injury by killing frost on April 6. April was normal in temperature with more than twice the normal precipitation. May was 5.3° warmer, June and July somewhat cooler than the average. August and October were dry and hot, while September was 4° subnormal. The year ended with an accumulated excess of temperature of 321°, the period March 1 to September 30 having 210° of the total. The frostless period extended from April 16 to October 23.

The percentage of sunshine received in February, March, May, and November was considerably above normal, March having 74 per cent of the total possible sunshine as compared with the normal of 51 per cent. May and December had subnormal sunshine combined with above-normal precipitation, while October combined low sunshine with high temperature and little more than one-fourth the normal rainfall. June to September, inclusive, very closely approximated the normal. The total hours of sunshine for the year were 2,679.2 as against a normal of 2,581.4; for the period March 1 to October 1 the total was 1,853.2 hours, an excess of 102.3 hours over the normal average for the period.

The rainfall for the year was materially below normal. November and December of 1917 were dry, having only 2 inches of precipitation, while February had less than one-fourth the normal. Excesses in October and January failed to bring the total for the period October 1 to normal by 3.95 inches. March and April together had 11.62 inches instead of the normal 7.10, but the whole period May to November, inclusive, was one of subnormal rainfall. From March 1

to October 1 the total received was 23.49 inches instead of the normal 27.75. There was consequently a shortage of 8.26 inches in precipitation between October 1, 1917, and October 1, 1918—35.24 inches as against the normal 43.50—and the concentration of nearly one-third of this total in March and April, with persistent drought through the remainder of the season, undoubtedly operated to produce a greater deficiency of soil water toward the end of the growing

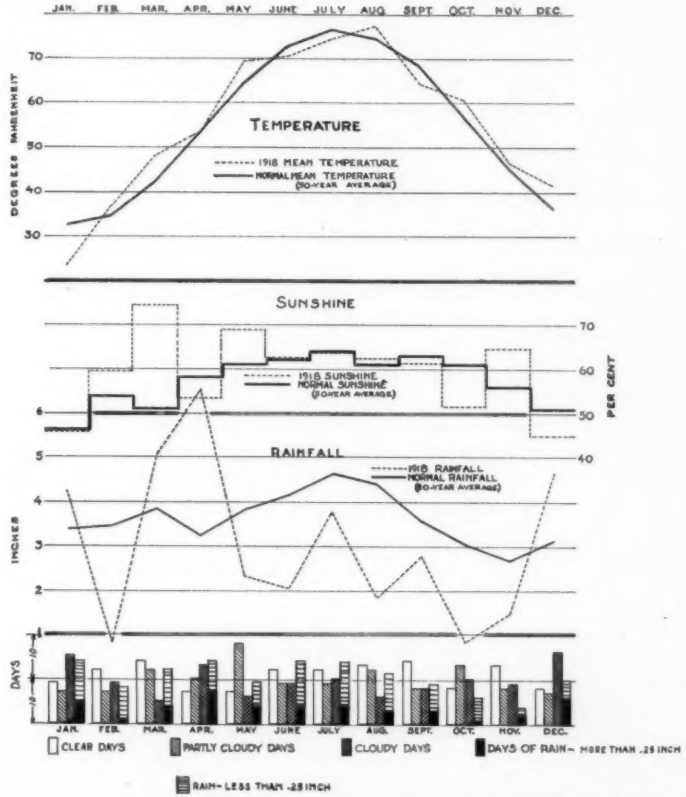

FIG. 1.—Climatic data (monthly mean temperature, sunshine, and rainfall) for Washington, D. C., for 1918, with 50-year average for comparison

season than the figures, considered without reference to distribution, would indicate. The subnormal temperatures during June, July, and September operated to reduce the rate of water loss by evaporation during these months, but the shortage was nevertheless large enough to be significant.

The climatic data for 1918, with 50-year average for comparison, are shown graphically in Figure 1.

CLIMATIC CONDITIONS IN 1919

It is immediately apparent from inspection of Figure 2 that 1919 was a year of consistently above-normal mean temperature. In only two months, August and December, were the averages below normal, and in August the deficiency was less than a degree. The winter months were mild and warm, December and January especially so, and only 3.3 inches of snow fell during the entire winter. While

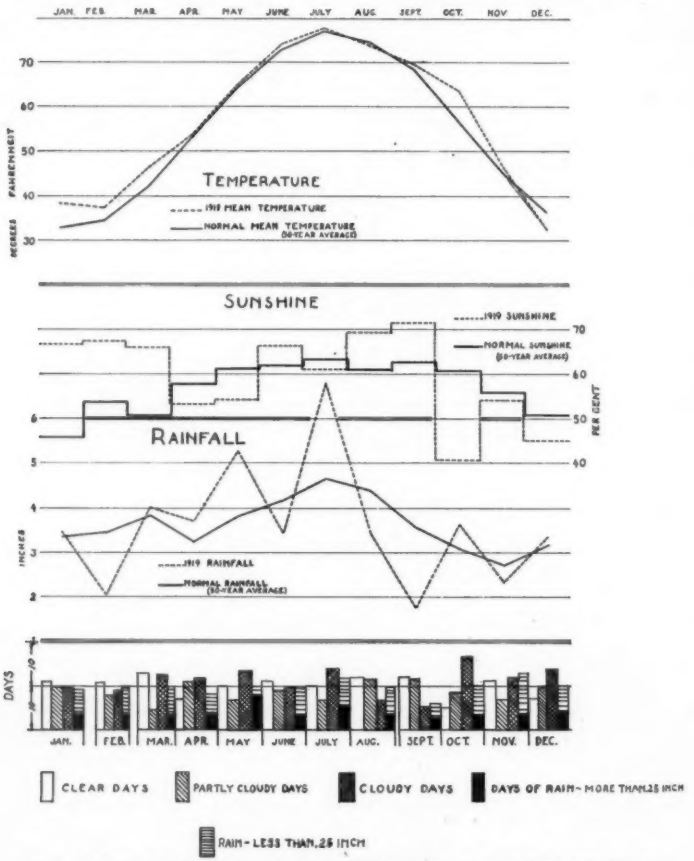

FIG. 2.—Climatic data (monthly mean temperature, sunshine, and rainfall) for Washington, D. C., for 1919, with 50-year average for comparison

March had a mean temperature of 4.4° F. above normal, minimum temperatures during both March and April were low enough to prevent premature development of fruit buds, so that very little damage was done by a succession of killing frosts on April 1, 2, 3, and 25 and 26. The departures from normal of the summer months were not large, so that while the calendar year had an excess of temperature of 616° only 226° of this accumulated during the growing

season (March 1 to September 30). The frostless season extended from April 26 to November 10, or three weeks later than the average date.

The percentages of sunshine received in the first three months of the year were exceptionally high, but April, May, and July were slightly subnormal. August and September had considerably more than the average. The total for the calendar year was 2,678.3 hours, as compared with the normal average of 2,581.4. For the period March 1 to October 1 the total was 1,835.8, an excess of 89.5 hours over the normal average of 1,749.9 for this period. The excess largely occurred in March, at the outset of the growing period, and in August and September, when the development of the crop was well toward completion. The rainfall of the year was unusual in that it closely approximated the normal in amount and distribution. There was a deficiency of 2.29 inches for the period October 1, 1918, to March 1, 1919, but for the growing season (March 1 to October 1) there was a total of 28.43 inches precipitation, or 0.68 inch more than normal.

CLIMATIC CONDITIONS IN 1920

In 1920 (fig. 3), with the exception of March, which had a mean temperature 3.4° F. in excess of the normal, the monthly temperatures from January to the end of July were all subnormal by 0.5° to 4.2°, May being notably cold. From August onward to the end of the year the monthly means were above normal by 0.4° to 4.5°. In consequence, an accumulated deficiency of temperature of 315° at the end of July was reduced to 23° at the end of the year. For the period March 1 to October 1 there was an accumulated deficiency of 104°. December, 1919, and January and February, 1920, were colder than normal, and there was a total of 16.4 inches of snow during the winter. The generally backward condition of vegetation prevented injury by the last frosts of spring, which occurred on April 10, 11, and 14. The first killing frost of autumn occurred on October 30, a week later than usual.

The amount of sunshine during the calendar year was only 32 hours under the normal, but distribution was decidedly abnormal. February, November, and December had large deficiencies, August somewhat less, while March, September, and especially October had excesses. Deficiencies in April and May were about equal in amount to the excesses in June and July. The period March 1 to October 1 had 30 hours more than the normal, nearly all of this being due to the excess in March at the outset of the growing season.

The rainfall for the calendar year was 3.09 inches below the normal. The deficiencies were due to shortages in January, March, May, and October which were not equaled by the excesses in April, June, July, August, and November. The shortage was at no time serious enough to be significant. (See fig. 9.) For the winter period, October 1 to March 1, it totaled 15.04 inches, only 0.71 inch less than normal; from March 1 to July 1 it amounted to 13.30 inches, or 1.80 less than normal; while from July to October it totaled 13.28 inches, or 0.64 inch more than normal. The shortage for the period October 1 to September 30 was consequently only 1.87 inch. The crop year therefore more nearly approached the normal in amount and distribution of both summer and winter rainfall than was the case in any other year of the period.

CLIMATIC CONDITIONS IN 1921

The year 1921 departed materially from normal in all respects. (Fig. 4.) The fall months of 1920 were warm, frost being delayed 10 days later than usual, and January and February were 3.7° and 4.5° F., respectively, above the normal. While there was 16.4 inches of snow during the winter, it at no time remained on the ground more than three or four days. March and April were the warmest on record in Virginia since the establishment of systematic records (*32*). The

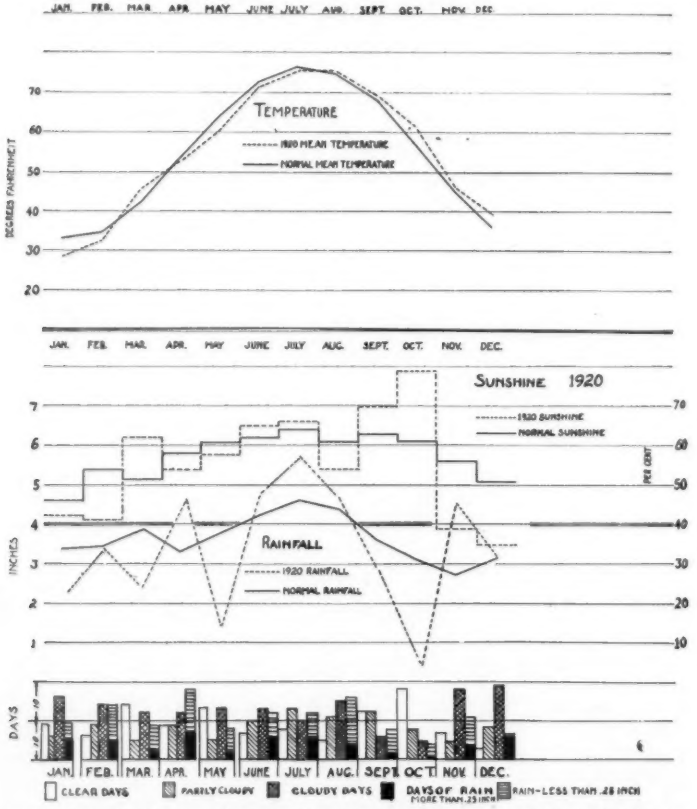

FIG. 3.—Climatic data (monthly mean temperature, sunshine, and rainfall) for Washington, D. C., for 1920, with 50-year average for comparison

minimum temperature recorded at Washington during March, 44.3°, is 2.2° above the normal mean for the month, while the mean was 13.4° above normal. The mean for April was 6° above normal. In consequence, growth was resumed very early, and was so far advanced that a cold wave accompanied by temperatures of 26° and 27° on March 29 and 30 did considerable damage, while killing frosts on April 2 and 11 were still more injurious, killing all but a very small percentage of fruit buds on most of the early-blooming varieties and causing considerable injury to the later varieties.

The year as a whole was hot and dry, only May and August having mean temperatures below the average. The accumulated excess of temperature for the year equaled 1,127° or an average daily excess of 3.1°. The year is characterized as "the warmest and driest year in Virginia since the beginning of State-wide records in 1891," and, further, as "one of the most unfavorable for agricultural interests ever experienced in Virginia" (*32*) and the data for the Washington

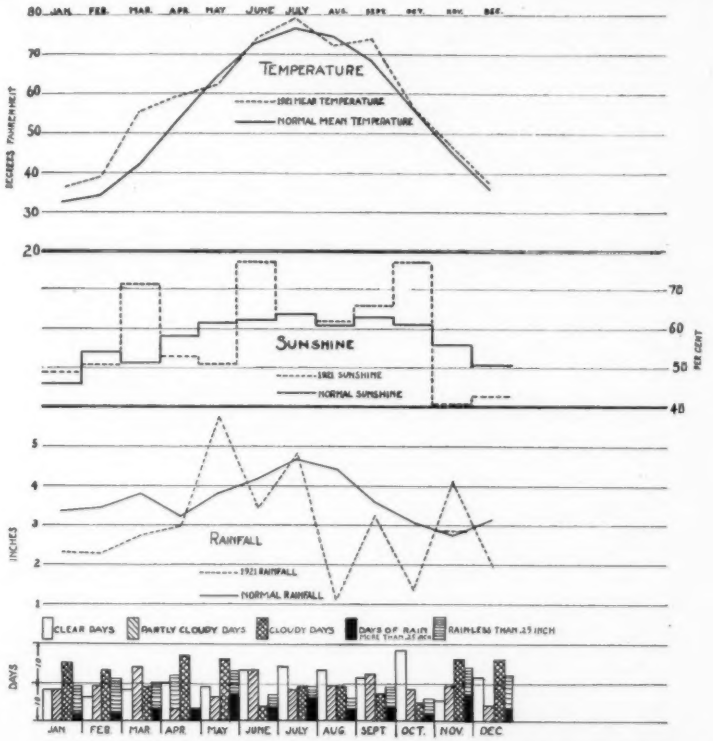

FIG. 4.—Climatic data (monthly mean temperature, sunshine, and rainfall) for Washington, D. C., for 1921, with 50-year average for comparison

station indicate that these statements may be applied without modification to the local conditions.

In so far as temperatures for the growing season are concerned, the period March 1 to October 1 accumulated an excess of 792°, or 3.7° per day. Much the larger portion of this total accumulated in April and the remainder in September, the net increase from May to the end of August being but 11°.

The distribution of sunshine for the year was abnormal. (See figs. 4 and 10.) The total amount was 2,666 hours, or 84.6 hours more than the average. Three months—March, June, and October—had notable excesses; April, May, and the last two months of the year had considerable deficiencies. More than the normal share of the

total was received between March 1 and the end of September, as this period had 1,846.7 hours instead of the normal 1,749.9.

Rainfall for the calendar year was deficient by 7.37 inches, the total being 36.13 inches. The first four months of the year were considerably deficient, August and October notably so. May had the largest precipitation for the year, but this exceeded the average by less than 2 inches. Considered on the basis of the crop year, October to February, inclusive, had 12.65 inches of precipitation, so that the

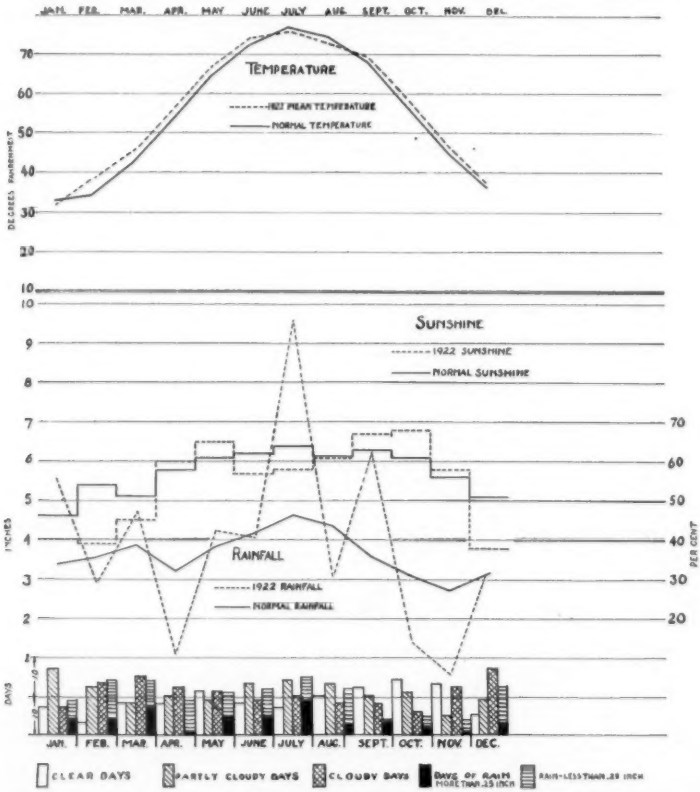

FIG. 5.—Climatic data (monthly mean temperature, sunshine, and rainfall) for Washington, D. C., for 1922, with 50-year average for comparison

growing season began with a shortage of 3.1 inches. The period March 1 to June 30 had 14.91 inches, only 0.2 inch less than normal, but the remainder of the growing season had only 9.18 inches, a shortage of 3.46. The actual shortage of available water was undoubtedly somewhat greater than the absolute deficiency of 6.77 inches for the year considered alone would indicate, since high temperatures and above-normal sunshine operated to increase surface evaporation from the soil and transpirational water loss from plants throughout the growing season.

CLIMATIC CONDITIONS IN 1922

The year 1922 (fig. 5) averaged 1.5° F. warmer than normal. January, July, and August were slightly below the average, but all the other months ranged above it by amounts varying from 1.8° to 4.2°. The temperatures of the late months of 1921 were all above the normal, and the winter was mild. Snow fell in December, January, February, and March, but the unusual total of 44.5 inches was due to the fall of 26 inches on January 27 and 28. With the exception of this heavy fall, some of which remained on the ground until late in February, the ground was bare except for two to four days at a time throughout the winter. The warm winter and spring resulted in early awakening of fruit trees, with the result that apple trees were rather generally coming into full bloom when a series of frosts occurred on April 21 to 29. The damage ranged from 25 to 75 per cent in commercial orchards. Some early blooming varieties in the variety collection escaped with only negligible damage. The growing period, March to September, was slightly less warm than the year as a whole, the daily excess of temperature being 1.34°.

Sunshine was subnormal in the first three months of the year, in slight excess in April and May, below average in June and July, and again in excess in September and October. The total for the year was 2,477.2 hours, or 104.2 hours less than normal; but the period March 1 to September 30 had 1,714.1 hours, or only 35.7 less than the average for these months.

Rainfall was 3.46 inches in excess of normal for the calendar year. July was the wettest since 1905, having 9.59 inches, while the 0.55 inch recorded for November is the smallest precipitation occurring in that month since 1871. Considered on the basis of the crop year, the precipitation from October, 1921, to March was 15.89 inches, or 0.12 more than normal; that for March to July 14.16 inches, or 0.95 less than normal; that for July to October 18.94, or 6.3 more than normal. The total for the crop year was 48.99 inches, or 5.49 inches more than the 50-year average.

The crop year was consequently slightly deficient in sunshine, had a material excess of heat well distributed through the season, and a large excess of precipitation, concentrated in the last half of the growing season.

CLIMATIC CONDITIONS IN 1923

Mean temperatures for 1923 departed materially from the average only in January, March, June, and December. (Fig. 6.) In the remaining months the means were within 1° F. or less of the average, except in September and October, which were, respectively, 1.5° above and 1.3° below normal. The mean for December was the highest ever recorded by the Washington station for the month, with the exception of the year 1886. While March and April were above normal in their mean temperatures, early resumption of growth was prevented by minimum temperatures of 21° and 19° F., respectively, on March 19 and 20, and of 18° and 15° on March 29 and April 1, with minima near or below freezing preceding and following these dates.[4] In consequence, heavy frosts on April 7, 9, and 10, with a light sleet storm on the 14th and 15th, did no damage to apples.

[4] The figures given are taken from the Monthly Meteorological Summary, Form 1030, for Washington, March, 1923 (*51*).

The growing season was warmer than normal by an average of 0.85° per day, the excesses of March, April, and June considerably exceeding the deficiencies of July and August.

The period March 1 to June 30 was remarkable for the large excess of sunshine in every month. The total of 1,185.1 hours is in excess of the normal by 218 hours. That the growth and development of crops was appreciably accelerated by the increased photosynthetic activity thus made possible is evident when it is considered

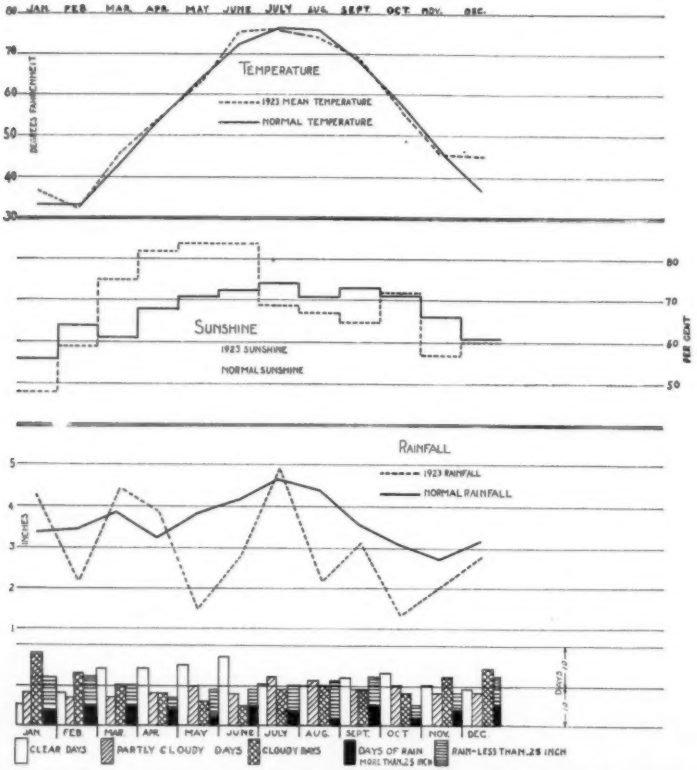

FIG. 6.—Climatic data (monthly mean temperature, sunshine, and rainfall) for Washington, D. C., for 1923, with 50-year average for comparison

that the effect is that of adding 17 days, each with 13 hours' continuous sunshine, to the effective working time of plants during the period. For the remainder of the growing season sunlight was consistently subnormal, July, August, and September having deficiencies totaling 66.6 hours. The growing season had a total of 1,901.4 hours, or 151.5 more than normal, but its distribution over the growing period was such as to accelerate development in the first half and to retard it in the last half of the season.

The precipitation for the calendar year was 7.9 inches below the normal. Snowfall was two-thirds the average. Only four

months had rainfall exceeding the normal, and the excesses were in all cases small. Deficiencies in October and November of 1922 resulted in a shortage of 8.66 inches for the crop year ending September 30. The winter period had a deficiency of 3.88 inches, March 1 to July 1 a deficiency of 2.40 inches, and the remainder of the growing season a further deficiency of 2.38 inches. There was consequently a soil-water deficit at the outset of the crop season which was never even momentarily made up, but which steadily

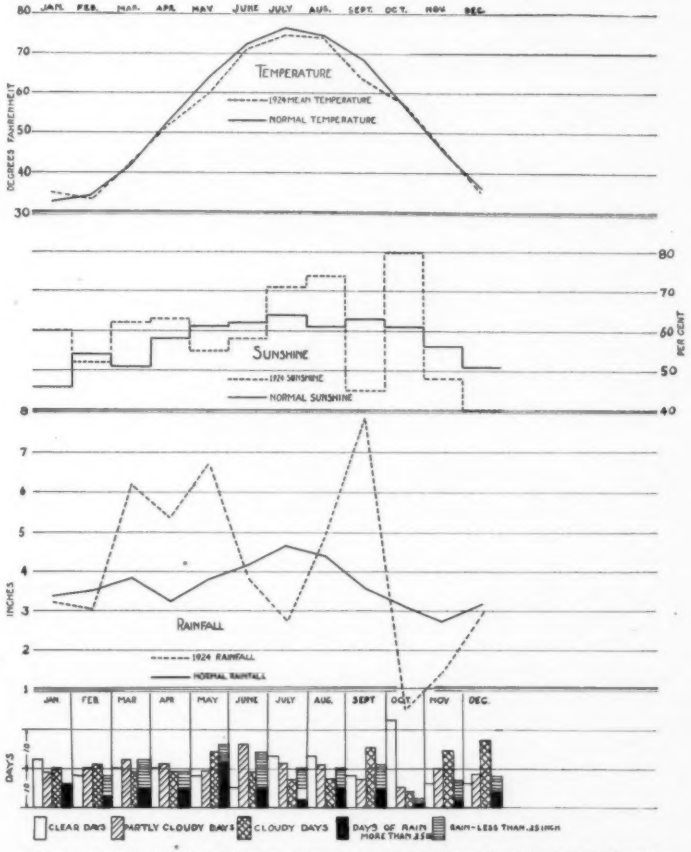

FIG. 7.—Climatic data (monthly mean temperature, sunshine, and rainfall) for Washington, D. C., for 1924, with 50-year average for comparison

increased through the entire period of growth and maturity. Stated in another way, the soil received in the 12 months ending October 1 only the amount of precipitation normally received by the end of July.

CLIMATIC CONDITIONS IN 1924

The year 1924 was cold and wet, yet had slightly more than the normal amount of sunlight. (Fig. 7; see also figs. 9 and 10.) The entire spring and summer were consistently subnormal in tempera-

ture, an accumulated excess of 17° F. at the end of February being converted into a deficiency of 341° at the end of September, or an average daily deficiency for the season of 1.67°. May was exceptionally cool, having a daily deficiency of 3.7° associated with high rainfall and subnormal sunlight, but was exceeded in all these respects by September, which had a mean temperature of 3.9° below normal, only 71 per cent of the normal hours of sunshine, and more than twice the average precipitation. Considered upon either the calendar-year or the crop-year basis, 1924 was by a considerable margin the coldest season of the period covered by these studies

The sunshine for the year exceeded the normal by 68.7 hours. Its distribution was such that the months, March to September, inclusive, received 37.4 hours more than the normal, a little more than half of the excess being received prior to July 1. The fluctuations from month to month can be better appreciated from the graphic record (figs. 7 and 10) than from a statistical statement.

Rainfall was in considerable excess for the year, especially in the spring months. The heavy precipitation in March canceled a deficiency of 3.29 inches which had resulted from subnormal rainfall in each of the five months from October to February, inclusive. The four months ending June 30 had 22.18 inches of rain, an excess of 7.07 inches, while the three months ending September 30 had 3 inches more than the normal. The growing period of seven months thus had a total of 37.82 inches, or an excess of 10.07 inches. This amount exceeds the totals received in the 12 months ending September 30 in the years 1918, 1921, 1923, and 1925.

CLIMATIC CONDITIONS IN 1925

The year 1925 showed material departures from normality in rainfall, sunshine, and temperature. (Fig. 8.) February was 7.8° warmer than usual, a record previously equaled only in 1890 and 1909. March and April had averages 3.8° and 3.6° F., respectively, in excess of normal, May was 3° subnormal, and June was the hottest month of the year, with 5.2° daily excess. September had a daily excess of 4.7°, while October was cold, with a daily deficiency of 5.3°. An accumulated excess of temperature of 204° at the end of February increased to 491° at the end of June and to 569° at the end of September. The four months March to June, inclusive, had an average daily excess of 2.35°, while the remaining three months of the growing season had an average of 0.86° per day.

The first six months of the year each had more than the average amount of sunshine, the excess from March 1 to the end of June totaling 151.8 hours. This is the equivalent of the addition to the period of 12 days each having 12.6 hours of uninterrupted sunshine. July had a deficiency which was not quite balanced by the excess of August, and the deficiency in September reduced the total for the three months to 720 hours, which is 63 hours less than normal for the period. (See figs. 10 and 12.)

The rainfall for the crop year ending October 1 was the smallest for any year of the period under study. From October 1, 1924, to March 1, 1925, the total, 10.31 inches, is less than two-thirds the normal amount for this period. It must be noted, however, that torrential rains occured over most of Maryland and Virginia on September 29 and 30, the total precipitation for the two days at Washington

equaling 5.44 inches. While the character of this downpour resulted in maximum run-off, it undoubtedly contributed in some degree to the stored soil water, with the result that the shortage on March 1, 1925, was actually somewhat less than the 5.44 inches indicated by comparison of the figures for precipitation between October 1 and April 30 with the normal.

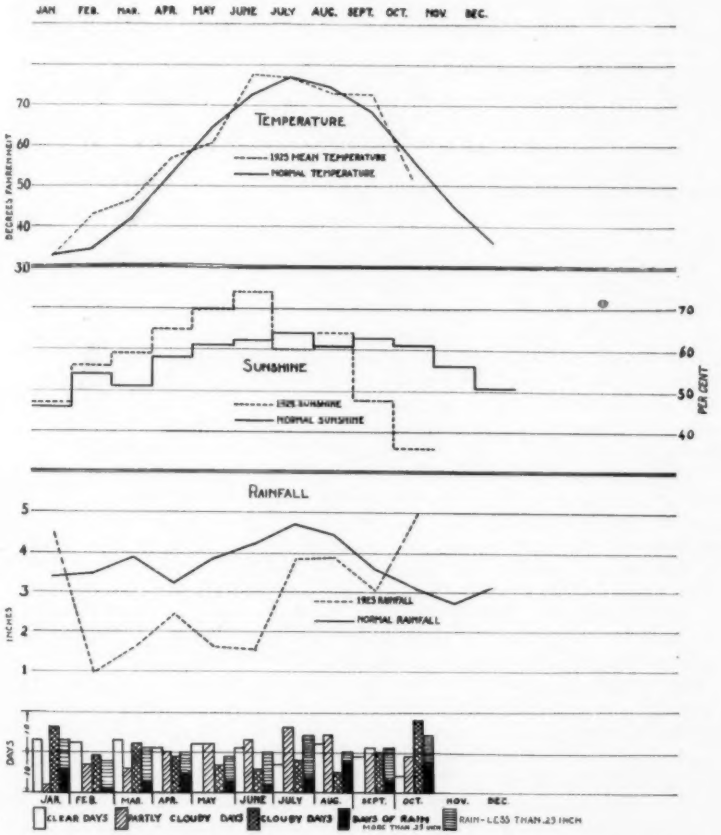

FIG. 8.—Climatic data (monthly mean temperature, sunshine, and rainfall) for Washington, D. C., for 1925, with 50-year average for comparison

The entire growing period was characterized by consistently subnormal rainfall in every month. The amount received from March 1 to the end of June was only 7.24 inches, not quite 48 per cent of the average. The last three months of the growing period had a deficiency of 1.91 inches. The total for the year ending October 1 was 28.31 inches, a deficit of 15.20 inches, or 34.2 per cent. The growing period had 18 inches, which is less than two-thirds the normal of 27.75 inches and less than one-half the high total of 37.87 inches for this period occurring in 1924.

CLIMATIC DATA IN RELATION TO CROP PERFORMANCE

In the preceding section the data for rainfall, sunshine, and temperature for each of the calendar years under study have been compared with the normal or 50-year average, and the extent of the departures from normal in amount and distribution of each of these factors has been stated. Such treatment gives a conception of any individual year as a unit in terms of the normal, as colder, drier, or wetter than the average, but it does not permit satisfactory direct comparison of one year with another or permit such a mental grasp of the conditions during a series of years as enables their evaluation in terms of the response of plants. In order to compare the climatic data for the series of years with relation to the production of crops, a rearrangement is necessary. Such a rearrangement has been made in Tables 9 to 12 and in Figures 9 to 12 on the basis of a crop year beginning October 1 and ending September 20.

The employment of the date of the first killing frost as the end of the crop year would involve comparison of periods of varying length. October 1, which in this latitude is very nearly the middle of the apple harvest, appears to fit the case better than any other arbitrarily chosen date could do. It has already been used by Shaw (*30*) as the end of the growing season. The crop year has been further arbitrarily divided into an inactive or dormant period, beginning October 1 and ending March 1, and a period of active growth, extending from March 1 to September 30. This division, which has also been employed by Shaw (*30*), has as its justification the fact that while the period of dormancy is far from being one of inactivity, the activities of the plant are not such as can be easily measured. The plant gives no immediate response which can be detected to the variations in intensity of the climatic factors, their effect becoming evident only as they affect the behavior of the tree during the succeeding period of active growth. In the active period the amounts of rainfall, heat, and sunshine received and their distribution in time are directly effective in determining the rate at which the life processes may go on, and their fluctuations from day to day determine the amount of vegetative growth and the quantity and quality of fruit produced.

The selection of March 1 as an arbitrary date for beginning the growing season has much to support it. It is rather well established that for a very wide range of plants a mean daily temperature approximating 40° F. represents a lower limit beyond which appreciable growth does not occur (*1, 13, 19, 28*), and this rounded figure is generally adopted as the approximate minimum temperature for growth. This study deals with a large number of horticultural varieties which show very considerable differences in the readiness with which they respond visibly to the increasing temperatures of spring. The date at which the daily mean temperature first equals 40° may be employed as a starting point for the active period with such an assemblage of forms, since the purpose of establishing such a point is merely to enable a comparison of like periods of time in various years with one another and with a "normal."

Adopting this conventional figure, it is found from the records of the Washington station [5] that the normal mean daily temperature at that station reaches 38° F. on February 27, 39° on March 3, and 40° on March 7. As the average mean temperatures for March exceeded the normal in every year of this study by 3.1° to 13.4° except in 1924, which was exactly normal, no material error will be involved in fixing upon March 1 as the beginning of the growing season, which will be considered as consisting of the seven months from March to September, inclusive.

For purposes of comparison the growing period is divided into two portions, that prior and that subsequent to July 1. The period March 1 to July 1 is that in which the tree develops its foliage and blossoms, and it includes the critical periods in which the tree may respond to unfavorable conditions by cutting down its load of fruit through dropping. The period subsequent to July 1 begins at a time when the load of fruit on the tree has been determined; the tree does not subsequently respond to unfavorable conditions by dropping its fruits. July 1 is about the time at which the "rest period," indicated by the formation of terminal buds, begins in the apple (*21*, *14*, *17*). Gourley (*18*) found that the annual increase in length of apple twigs in New Hampshire was largely completed by the end of June. Conditions during the period July 1 to October 1 will determine the size, color, keeping quality, and time of maturity of the fruit, the production of fruit buds for the next crop, and the amount of food reserves accumulated in the tree for use in the succeeding year.

It is obvious that the dates chosen in no sense mark the limits of definite phases of the activities of plants. The plant does not pass suddenly from quiescence to activity, or the reverse, like a machine controlled by a switch; the transitions are gradual and merge insensibly one into another. Nor does it do only one thing at a time; the various activities of the plant overlap. Transformations of reserves, extension of the vegetative system, and development of the crop go on concurrently; maturing of the crop, formation of next year's fruit buds, and storage of reserves for next year's activities occur together. The so-called dormant season is a period of chemical activity which bulks large in its effects upon the accomplishment of the tree in the following active period. It is clear, however, that there are periods of the year in which one or another group of activities are dominant and in which climatic conditions will express themselves in the behavior of the plant primarily through the effects produced upon the dominant activity of the period concerned. Considering the period October 1 to February 28 as primarily one of chemical preparation of materials for next season's use, that from March 1 to July 1 as a period of construction in which accumulated reserves and daily income through photosynthesis are expended in growth, and that from July 1 to September 30 as one of completion of the year's undertakings and of building

[5] Monthly Meteorological Summary, Form 1030, for Washington, D. C., March, 1920, and March, 1925 (*31*). Normal daily mean temperatures are not directly stated, but are arrived at by adding or subtracting the "departures from normal" from the recorded daily means. Departures from normal are not included in the Monthly Summary for Washington prior to February, 1920.

reserves for the next year, climatic conditions in any period will be considered as affecting the dominant activity of that period. On this basis, comparison of a series of years one with another can be made.

A rearrangement of the weather data on the basis of crop years, beginning October 1 and ending September 30, for the period from October 1, 1917, to October 1, 1925, has been made in Tables 9 to 12 and in Figures 9 to 12. The considerations which have governed in

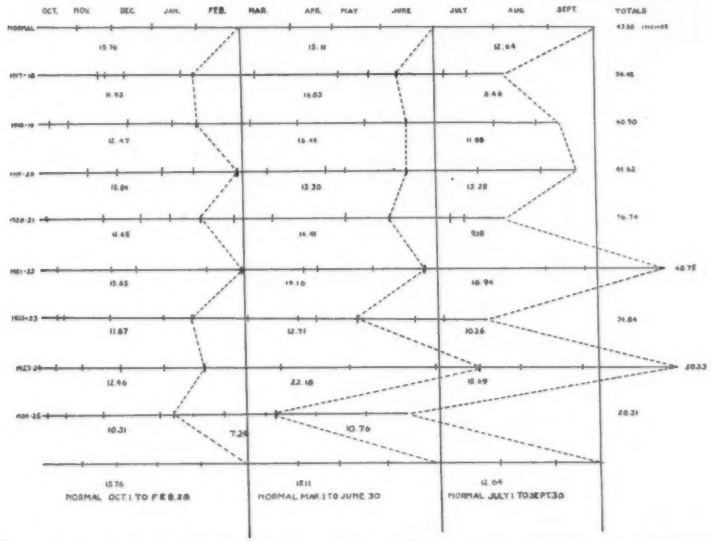

FIG. 9.—Rainfall by months and by periods for the crop year (October 1 to September 30) for the years 1918–1925, with normal 50-year average for comparison. Normal for each period is indicated by vertical lines; broken lines indicate departures from normal for each period in the various years

the adoption of the methods employed in the rearrangement of the data may be stated at the outset.

In Table 9 the amount of rainfall for each month and the totals for each of the three periods of each crop year, with departures from the normal 50-year average, are stated for each of the crop years. Figure 9 presents the data graphically. Sunshine, which was represented in graphs for the individual years (figs. 1 to 8) as percentages of the total possible sunshine, has been recalculated from the Weather Bureau data as actual hours of sunshine per month and compared with the normal similarly recalculated, with departures from normal, for the same periods as the rainfall (Table 10 and fig. 10).

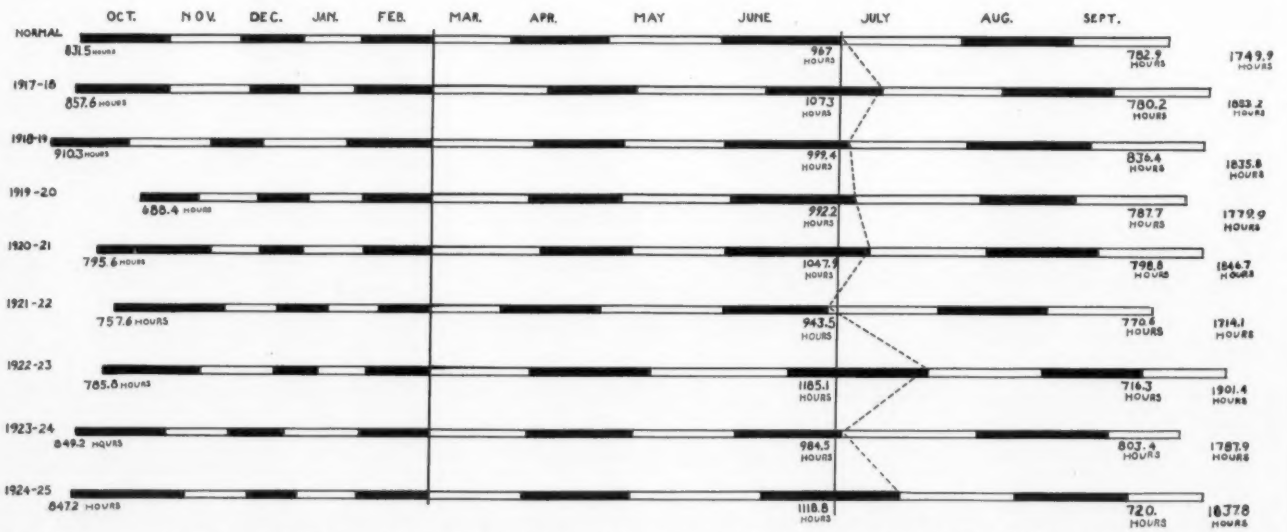

FIG. 10.—Hours of sunshine by months for the years 1918–1925, with normal for comparison. The vertical line representing March 1 is a line of reference, sunshine for October 1 to February 28 being plotted to the left and that for March 1 to September 30 to the right. The broken line connects the totals for the period March 1 to June 30 with normal for the period

TABLE 9.—*Rainfall (in inches) by months and by periods for the years 1918–1925, with normal for comparison*

Year	October to February							March to June						July to September					Total, 12 months	Departure from normal 12 months	Total for growing period (March–September)
	October	November	December	January	February	Total for period	Departure from normal	March	April	May	June	Total for period	Departure from normal	July	August	September	Total for period	Departure from normal			
Normal (50-year average)	3.09	2.71	3.16	3.38	3.42	15.76	0	3.85	3.25	3.83	4.18	15.11	0	4.65	4.40	3.59	12.64	0	43.51	0	27.75
1918	4.81	.53	1.47	4.29	.83	11.93	−3.83	5.04	6.58	2.35	2.06	16.03	+.92	3.79	1.88	2.79	8.46	−4.18	36.42	−7.09	24.49
1919	.86	1.48	4.65	3.47	2.01	12.47	−3.29	4.02	3.72	5.27	3.44	16.45	+1.34	6.80	3.41	1.77	11.98	−.66	40.90	−2.61	28.43
1920	3.64	2.31	3.32	2.30	3.47	15.04	−.72	2.39	4.69	1.42	4.80	13.30	−1.81	5.71	4.70	2.87	13.28	−.64	41.62	−1.89	26.58
1921	.40	4.51	3.15	2.30	2.29	12.65	−3.11	2.76	2.93	5.77	3.45	14.91	−.20	4.79	1.10	3.29	9.18	−3.46	36.74	−6.77	24.09
1922	1.35	4.15	1.95	5.34	2.86	15.65	−.11	4.74	1.05	4.27	4.10	14.16	−.95	9.59	3.08	6.27	18.94	+6.30	48.75	+5.24	33.10
1923	1.41	.55	3.48	4.24	2.19	11.87	−3.89	4.47	3.94	1.50	2.80	12.71	−2.40	4.92	2.19	3.15	10.26	−2.38	34.84	−8.67	22.97
1924	1.36	2.04	2.80	3.21	3.05	12.46	−3.30	6.17	5.39	6.73	3.89	22.18	+7.07	2.76	5.07	7.86	15.69	+3.05	50.33	+6.82	37.87
1225	.44	1.47	2.98	4.44	.98	10.31	−5.45	1.60	2.44	1.67	1.53	7.24	−7.87	3.82	3.89	3.05	10.76	−1.88	28.31	−15.20	18.00

TABLE 10.—*Hours of sunshine by months and by periods for the years 1918–1925, with normal for comparison*

Year	October to February							March to June						July to September					Total, 12 months	Departure from normal 12 months	Total for growing period (March–September)
	October	November	December	January	February	Total for period	Departure from normal	March	April	May	June	Total for period	Departure from normal	July	August	September	Total for period	Departure from normal			
Normal (50-year average)	211.2	168.8	149.6	139.4	162.5	831.5	0	189.2	230.5	270.8	276.5	967.0	0	289.6	258.3	235.0	782.9	0	2,581.4	0	1,749.9
1918	219.8	189.0	129.4	140.0	179.4	857.6	+26.1	275.7	211.8	305.9	279.6	1,073.0	+106.0	287.4	263.8	229.0	780.2	−2.7	2,710.8	+129.4	1,853.2
1919	179.6	195.0	132.0	200.2	203.5	910.3	+78.8	245.3	214.2	242.4	297.5	999.4	+32.4	277.0	293.0	266.4	836.4	+53.5	2,746.1	+164.7	1,835.8
1920	141.9	164.0	132.9	126.2	123.4	688.4	−143.1	230.0	214.6	257.5	290.1	992.2	+25.2	297.4	228.3	262.0	787.7	+4.8	2,468.3	−113.1	1,779.9
1921	273.9	118.3	101.7	148.5	153.2	795.6	−35.9	264.5	211.4	226.8	345.2	1,047.9	+80.9	287.9	264.0	246.9	798.8	+15.9	2,642.3	+60.9	1,846.7
1922	267.8	122.8	127.0	122.4	117.6	757.6	−73.9	166.6	236.6	287.1	253.2	943.5	−23.5	262.4	257.5	250.7	770.6	−12.3	2,471.7	−109.7	1,714.1
1923	236.8	174.3	112.0	116.6	146.1	785.8	−45.7	239.6	284.9	329.9	330.7	1,185.1	+218.1	269.0	240.9	206.4	716.3	−66.6	2,687.2	+105.8	1,901.4
1924	215.9	143.3	145.5	181.4	163.1	849.2	+17.7	231.5	251.3	244.4	257.3	984.5	+17.5	321.1	312.7	169.0	802.8	+19.9	2,636.5	+55.1	1,787.3
1925	275.9	144.7	116.7	141.5	168.4	847.2	+15.7	219.7	257.9	310.4	330.8	1,118.8	+151.8	269.3	270.1	180.2	719.6	−63.3	2,685.6	+104.2	1,838.4

Temperature, which has been expressed in the graphs for individual years in the conventional way, by curves showing the departures of monthly mean temperatures from the normal mean, is expressed in Table 11 and Figure 11 on the basis generally adopted in studies of temperature in relation to plant behavior, namely, the summation of temperatures above a base line. While various points on the thermometer scale have been adopted by different workers, 32° F. has been most widely employed as a basis from which to make summations. This seems rather illogical, since it includes in the summation daily heat units well below the minimum for growth. It seems much more rational to adopt the suggestion of Duggar (*15*) that an approximate growth minimum be taken as a basis and that the difference

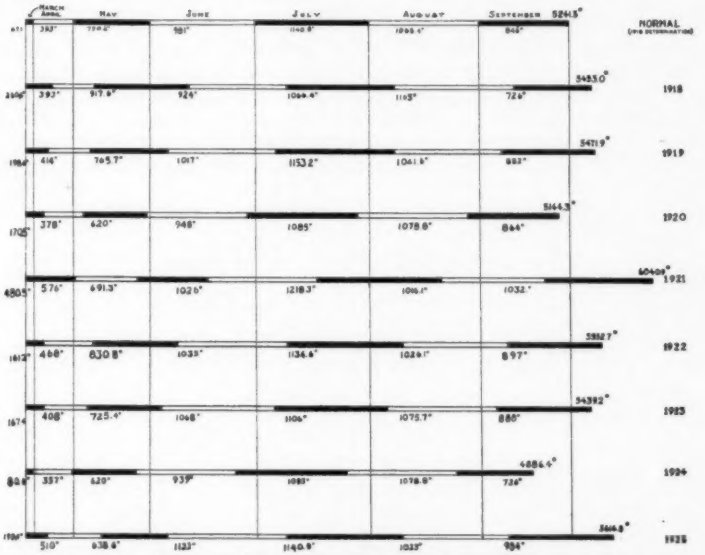

FIG. 11.—Total heat in excess of 40° F. daily received during the months of March to September, inclusive, for the years 1918–1925, with normal for comparison

between this and the daily mean be taken to represent the daily efficiency during the growing season. He suggests 40° F. as the growth minimum. It has been used by McLean (*26*) and by others, and has been employed by Livingston (*24*, *25*) in his attack upon the problem of integrating temperature values in relation to plant growth. The conventional constant of 40° F. is consequently here employed as the minimum temperature or zero point from which the summations are made.[6] The results are presented in Table 11 and in Figures 11 and 12.

[6] The various totals of heat units above 40° F. given in Table 11 can be converted into heat units above 32° by increasing each by 1,712° (the product of multiplying the 214 days of the growing period by 8, the difference between 32° and 40°) or by a similar method for the shorter periods. Such treatment, of course, does not in any way affect the amounts of the departures from normal given in the table.

TABLE 11.—*Summation of heat units above 40° F. (in degrees Fahrenheit) from March to September inclusive, for the years 1918–1925, with departures from normal year*

Year	Mar. 1 to June 30	Departure from normal	July 1 to Sept. 30	Departure from normal	Total, Mar. 1 to Sept. 30	Departure from normal
Normal	2,188.3	0	3,053.2	0	5,241.5	0
1918	2,495.0	+306.7	2,958.0	−95.2	5,453.0	+211.5
1919	2,395.1	+206.8	3,076.8	+23.6	5,471.9	+230.4
1920	2,116.5	−71.8	3,027.8	−25.4	5,144.3	−97.2
1921	2,773.8	+585.5	3,267.1	+213.9	6,040.9	+799.4
1922	2,495.0	+306.7	3,057.7	+4.5	5,552.7	+311.2
1923	2,368.8	+180.5	3,070.4	+17.2	5,439.2	+197.7
1924	1,996.6	−191.7	2,889.8	−163.4	4,886.4	−355.1
1925	2,469.0	+280.7	3,147.8	+94.6	5,616.8	+375.3

The method employed in arriving at summations of temperatures when short periods are under consideration is to subtract the zero point from the mean temperature of each day and add the remainders. The application of this method to a long series of years is very laborious. A very close approximation to the true values can be arrived at by subtracting the zero value, in this case 40° F., from each of the

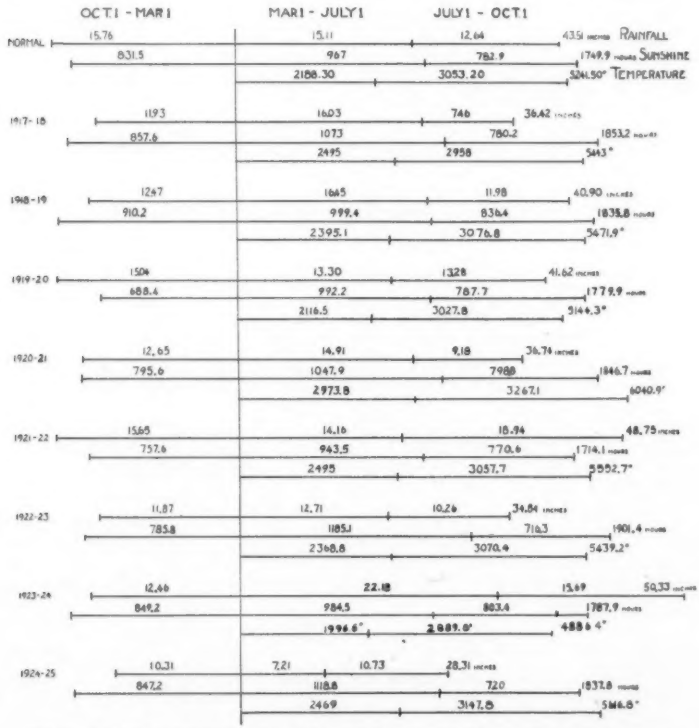

FIG. 12.—Collective summary of climatic data for the years 1918–1925, with normals for comparison. The vertical line representing March 1 is a line of reference, rainfall and sunshine for October 1 to February 28, inclusive, being plotted to the left, and these items with temperature in excess of 40° F. for the period March 1 to September 30, inclusive, to the right

monthly means and multiplying the remainder by the number of days in the month. Values so obtained will differ from the true values only if some of the daily means fall below the constant used as a zero point. Such days are left out in the day-by-day summation, but are included in making up the monthly mean, which they render lower in value. As a matter of fact days with a mean temperature below 40° occur during the growing period in this latitude only in early March and are so infrequent that the error involved in neglecting them is insignificant.

In the case of the period from October 1 to February 28 summations of temperature can not be computed from 40° F. as a basis, since many of the means are below this figure. Some other method must be employed. The ultimate result of any method which can be used is the obtaining of a figure which can be compared with the normal or average, which is everywhere employed as a standard of comparison. The most satisfactory method of obtaining a figure which will give a conception of the character of temperature for the winter period as a whole is to employ the 50-year average as a normal or base line and to sum up the departures, positive or negative, from this normal for each year under consideration. Such a summation, in conjunction with a statement of the amount and character of the departures from normal month by month, is given in Table 12.

No winter injury occurred at any time during the period of the work, and there is no indication that winter temperatures at any time affected the condition or fruitfulness of the trees.

TABLE 12.—*Comparative departures of mean temperatures (in degrees Fahrenheit) from the normal mean temperatures from October to February, inclusive, for the years 1917–1925*

Year	October	November	December	January	February	Total
1917–18	−147	−71	−253	−287	+65	−693
1918–19	+126	+37	+170	+163	+75	+571
1919–20	+206	+55	−109	−128	−53	−29
1920–21	+140	+24	+98	+115	+126	+503
1921–22	+10	+77	+7	−29	+117	+182
1922–23	+63	+79	+33	+107	−79	+203
1923–24	−39	−2	+261	+51	−34	+237
1924–25	+7	+24	−6	−13	+217	+229

COMPARATIVE SUMMARY OF CLIMATIC DATA

Separate comparisons of the data upon the individual climatic factors for the various years of the period under study will facilitate the consideration of these factors taken collectively in an attempt to evaluate them in terms of their effect upon the plant.

RAINFALL

It is immediately obvious from inspection of Figures 9, 10, and 11 that of the three climatic factors considered, rainfall is that which displays largest departures from normality both in amount and distribution. When the rainfall records for the crop years (October 1 to September 30) are compared among themselves, several generalizations can be formulated. (See fig. 9.) The crop years 1919 and 1920 are nearest to normal both in total amount of rainfall and in its

distribution through the year. The departures from normal are such as to preclude the possibility that precipitation, considered alone, has been a limiting factor in crop production, and these years may stand as normals so far as this factor alone is concerned. If an excess of 5 to 7 inches for the year, largely concentrated in the growing season, measurably affects the composition and quality of the crop as a whole, 1922 and 1924 should show such effects. If reduction of rainfall for the crop year by 6 to 9 inches affects the crop in a definite manner, 1918, 1921, and 1923 should show such effect, and an intensification of such effect should be evident in 1925. Extremes in water supply during the growing season are presented by 1924 with 37.87 inches and 1925 with 18 inches, and any effects upon crop composition due solely or predominantly to excess or deficiency of precipitation should be apparent when the crops of these years are compared, employing the crop of 1920 as a standard. Summarizing, 1919 and 1920 approach normal very closely; 1918, 1921, and 1923 are years of moderate deficiency; 1925 is one of extreme deficiency; and 1922 and 1924 are years of very considerable excess in precipitation.

SUNSHINE

Total hours of sunshine per crop year show a considerably narrower range of variation than does rainfall. This factor has fallen below normal only twice, in 1920 and in 1922, exceeding the average in all the other years. (See fig. 10.) It has materially exceeded the normal for the late autumn and winter months only once, in 1919; it was very close thereto in 1918, 1924, and 1925, and was considerably deficient during this period in 1920 to 1923, inclusive. For the growing season it has been subnormal in one year only, 1922, and that by only 2 per cent of the normal total. In 1920 and 1924 the totals received exceeded the normal by 30 and 37 hours, respectively, or approximately 2 per cent. These differences are certainly too small to be of significance, and 1920, 1922, and 1924 may be considered as normals with respect to this factor. In 1918, 1919, 1921, and 1925 there were excesses ranging from 85 to 103 hours, or 5 to 6 per cent, while 1923 had an excess of 151.5 hours, or 8.5 per cent.

These increases in the working period of the photosynthetic apparatus, amounting as they do to 7 to 12 days of 12 hours uninterrupted sunshine each, are large enough to make recognizable additions to the work accomplished by trees during the season. Whether such increases may be expected to express themselves as increases in vegetative growth and load of fruit or as changes in the composition of the fruit can only be determined by examining the distribution of sunshine over the growing period. The years 1919 and 1925, for example, differed by only 2.6 hours in total sunshine for the season, but 1925 received 1,118.8 hours prior to July 1 as against 999.4 hours for 1919, while 1925 had 720 hours of sun between July 1 and September 30 in contrast with 836.4 hours for 1919. The two years were therefore very dissimilar, since one had a period of development 10 days longer and a period of maturation 10 days shorter than the other, so far as sunshine is concerned. The years 1922 and 1923 are extremes in point of sunshine received, as 1923 received 1,185.1 hours in the period March 1 to July 1, or 241.6 hours more than 1922, but for the period July 1 to September 30, 1923, had the greatest deficiency encountered during the period, 66.6 hours less than the

normal and 54.3 less than 1922. In consequence, 1923 had the largest amount of sunshine in the first half and the smallest amount in the latter half of the season found in the entire period. The results of excesses of 106 hours and 80.9 hours in the first half of the season in 1918 and 1921, followed by amounts close to normal in the second half, will be different in character from the results of 151.8 hours of excess sun in the first half of the 1925 season, followed by a period of maturity having 63.3 hours less than normal sunlight.

These instances serve to emphasize the fact that mere summation of the amount of a climatic factor, unaccompanied by consideration of its distribution over the growing period of the crop, does not give a dependable indication of the probable effect of that factor.

HEAT UNITS

There are very considerable variations in the amounts of heat received during the growing season. The years 1921 and 1924 present extremes, 1921 having heat units equaling 123.7 per cent of the total for 1924. (Fig. 11.) With the exception of 1920 and 1924, all the years had summations somewhat above the normal 50-year average. The year 1920 most nearly approached the normal, having a deficiency of 1.8 per cent, while 1924 had a deficiency of 6.7 per cent. The years 1923 and 1918 had excesses of 3.7 and 3.8 per cent, respectively; 1919, 4.3 per cent; 1922, 5.9 per cent; 1925, 7.1 per cent; 1921, 15.25 per cent. If excess or deficiency of heat units received is the dominant factor in determining the character of the crop in any of the years covered by this study, such dominance must manifest itself in the years 1921 and 1924. In distribution of the heat received over the growing season, 1920 and 1923 most nearly approach the normal, the former having a small deficiency, the latter a small excess at the end of each month, throughout the season. If considerable excesses of heat received prior to July 1 with approximately normal amounts thereafter exert recognizable effects, 1922, 1923, and 1918 should show such effects.

In order to form conceptions of the probable effects upon the productiveness of plants of the seasonal conditions of the series of years under study, it is necessary to employ a collective treatment of the data for each year in order to permit comparisons between years. In such a treatment it is indispensable that the conditions of some one year be selected as a standard with which those of the others may be compared. The year 1920 is best suited to serve as such a standard, since it more closely approximates the 50-year average than does any other of the series. The rainfall for the crop year, while falling short of the normal total by 1.89 inches, or 4.34 per cent, was nearer the normal and was also more evenly distributed over the three periods of the year than is the case in any other year. (Figs. 9 and 12.) While the temperatures for the individual winter months depart considerably fom the 50-year average, the total departure from the normal for the period October to February was only 29°, which is insignificant. (Table 12.) The heat units received during the growing season were 98.2 per cent of normal, and their distribution over the growing season was exceptionally uniform, May being the only month having much departure. (Fig. 11.) Total sunshine for the year had a deficiency of 113.1 hours, but this occurred in the winter months. March to June had an excess of 25.2 hours, July to September an

excess of 4.8 hours, the growing season thus having the closest approximation to the normal found in any year. (Table 10 and fig. 10.) The year consequently conforms very closely in all respects to the 50-year averages which make up the normal year.

It follows that in so far as climatic factors have determined its character and quality, the crop of 1920 should be a normal crop, having been produced under the influence of climatic factors in just the amount and with the distribution characteristic of the normal year. It does not follow that it was actually such in the sense in which the horticulturist employs the term, since he takes into account the effect of numerous nonclimatic factors in forming his estimate. These factors will be considered in a subsequent section, but it may be pointed out here that any departure of the 1920 crop from the orchardist's conception of a normal crop is to be attributed to nonclimatic factors.

The remaining years each show very considerable abnormalities in amount or distribution of one or more factors. Because of certain similarities, 1921 and 1923 may be considered together. There were deficiencies of rainfall and excesses of temperature and sunlight in both, 1921 being much the hottest year of the period, while 1923 had the largest amount of sunshine in the growing season. The year 1921 was deficient in rainfall in the winter months and in the late summer, with almost normal precipitation from March 1 to June 30. Growth began very early, and the conditions of normal rainfall, considerable excess of sunlight (80.9 hours), and large excess of temperature (585°) combined to accelerate the development of a crop which had been materially reduced in size by frosts. Sunshine was nearly normal in late summer, but July was hot, August had only one-fourth the normal rain, and September was exceptionally hot. In consequence, the crop completed its development and reached maturity under conditions of severe heat and drought.

The year 1923 had a larger deficiency of rainfall than 1921, somewhat differently distributed in that the shortage of the winter was followed by a shortage in May and June, which had little more than half the normal amount. Winter temperatures were in excess of normal until February, but resumption of growth was not hastened and there was no injury from frost. The whole period from March to June, inclusive, was remarkable for its large excess of sunshine in every month, totaling 218 hours in the four months. Temperatures were normal until June, which was quite warm. The period beginning July 1 had practically normal heat units, the largest deficiency in sunshine (66.6 hours) of any year of the series occurring in this period, and there was a shortage in August and September rainfall.

Summing up the likenesses and differences of the two years, 1921 had favorable conditions for the development of the crop until midsummer, with high temperatures and shortage of rainfall as unfavorable conditions for its maturity. The year 1923 had favorable conditions until midsummer, except that a shortage of rainfall in May and June may have had injurious effects. The conditions under which the crop matured were decidedly more favorable than those of 1921, being more nearly normal in temperature and rainfall although somewhat deficient in sunlight.

The year 1925 may be considered in connection with 1921 and 1923 for the reason that it presents in greater intensity the condition of deficient precipitation. With an approach to the high temperatures of the late winter and spring months which were striking features of the season of 1921, it combines an excess of sunshine second only to that occurring in 1923. After July 1, 1925 had a deficiency of sunlight almost equaling that of 1923, combined with a temperature record like that of 1921 in that it remained close to normal until September, then rose markedly above the average. The season was thus a composite of the others, but with the factor of shortage of precipitation greatly intensified. A larger shortage for the winter months than in any other year was combined with a reduction of the amount received in March to June, inclusive, to less than half the normal. The crop consequently developed under conditions of excess light and heat and serious water shortage, and was matured under conditions of deficiency of sunshine, increasing deficiency of water, and exceptionally high temperature, especially in the last month of the season. Of the three years in which shortage of water supply may have been a limiting factor, 1925 is that in which it obviously must have played the most significant rôle.

The years 1922 and 1924 are similar in that there were considerable excesses of precipitation in both, but in its distribution and in that of the other factors there is very little likeness. Both years had winter temperatures considerably above normal. but the excess in 1924 was mainly due to a very warm December, the later months being near normal. The whole growing season of 1924 was one of consistently subnormal temperatures, ending with a deficiency of 355° F. The period from March 1 to July 1, 1922, had an average daily mean temperature 4.1° higher than 1924. Hours of sunlight closely approximated the normal in this period in both years, but 1922 had slightly subnormal precipitation in contrast to the very large excess of 1924. After July 1, 1922 received almost exactly the normal amount of heat, about one day less than normal hours of sun, and a large excess of precipitation. The year 1924 had a deficiency of 163° of heat and a small excess of sunshine. Torrential rains totaling 5.44 inches on September 29 and 30 give this period an apparent excess of 3.5 inches of rain, but when it is considered that no part of the precipitation of September 29 and 30 was available for the crop it is seen that the water actually available during the period was somewhat subnormal. Consequently 1922 was a year of rather high temperatures with excessive rainfall during the period of late development and maturity of apples, and 1924 was one of persistently subnormal temperatures with excessive precipitation in the first half of the growing period.

Summarizing, 1920 closely approached normality in all its climatic factors. The year 1921 was subnormal in having large excess of temperature throughout the growing season, with deficient rainfall in the latter half; 1922 had high temperatures in the first half of the growing season and excessive rainfall in the second half; 1923 had a large excess of sunshine and a material deficiency of water prior to July 1, with subnormal sunshine and rainfall after that date; 1924 had a large deficiency in total heat received during the season, with excessive precipitation in the first half; and 1925 was extremely hot and dry throughout, with an excess of sunshine prior to July 1 and a deficiency thereafter.

RELATION OF SEASONAL CONDITIONS TO COMPOSITION OF THE CROP

In the preceding sections the climatic conditions during the period of the work have been discussed in considerable detail, and the analytical data have been considered with respect to the fluctuations in amount of various constituents occurring during the period. The analytical results show that the large group of varieties employed in the work display distinct mass tendencies, that is, they behave as one in very considerable degree in respect to the fluctuations in sugar, acid, and astringent substance occurring from year to year. It now remains to consider these mass tendencies, as they manifest themselves from year to year, in connection with the climatic data, and to ascertain in how far and in what way the character of the crop for each year, as measured by its composition, has been affected by the climatic conditions prevailing during the development of that crop. This can best be approached through a summation of the results of the analysis for the various years, followed by the consideration of the collective result for each year in relation to the climatic phenomena of that year.

Completeness of comparison of the analytical results is impossible, for the reason that the data upon sugar and acid content cover six years, 1920–1925, while data for astringent constituents are available for only the last four of these years. Consequently, any year may rank in any position from first to sixth with respect to sugar or acid content, but in only one of four positions in regard to astringent materials, since 1920 and 1921 can not be compared in this respect. The results are assembled in Table 13 so as to show the ranking of the various years with respect to the constituents mentioned.

TABLE 13.—*Comparative rank of the crops of the six years 1920–1925 in respect to sugar, acid, and astringent constituents*

[Rank of 1 indicates largest number of varieties having maximum content of the constituent indicated, 2 next largest, and so on. Comparisons are made for six years on total sugar and acid content and for four years on astringent substances]

Crop of—	Ranking of crop designated in—		
	Total sugar	Titratable acidity	Relative astringency
1920	5	4	----------
1921	2	1	----------
1922	4	3	2
1923	1	2	4
1924	6	5	1
1925	3	6	3

It is immediately apparent from an inspection of Table 13 that there is a considerable degree of correlation between sugar, acid, and relative astringency.

The year 1923 has maximum sugar content and next to maximum acidity, associated with minimum relative astringency. The year 1924 has minimum sugar and next to minimum acidity, together with maximum relative astringency. The years 1922 and 1925, which are intermediate in sugar, are also intermediate in astringent material, though 1925 has minimum acidity. The year 1920 has low sugar and rather low acidity; 1921 has high sugar and maximum acidity, but data on astringent materials are lacking.

It is evident that sugar content and acidity are rather definitely coupled as to amount, and that the relation with relative astringency is one of antagonism, sugar and acid content tending to minimum values as astringency approaches maximum, or the reverse.

The consideration of the relation of climatic conditions to the results may be begun with 1923, a year of extremes. Maximum sugar content in a very large number of varieties was associated with high acid content and with reduction of relative astringency to the lowest level encountered during the entire period. The amounts of cane sugar present were maximum for the whole period of the analyses in a large majority of the varieties analyzed.

The climatic conditions of 1923, as summarized in Figure 12 (see also figs. 9, 10, and 11), were remarkable for the very large excess of sunshine (218.1 hours) combined with moderately high temperatures (180.5° F. excess) in the period from March 1 to June 30. This was succeeded in the period from July 1 to September 30 by practically normal temperature (17.2° excess) and materially subnormal sunshine (66.2 hours deficiency). The two parts of the season thus present the extremes in the matter of sunshine found in the series of years, the maximum in the first portion of the season and the minimum in the latter portion. It is clear that the additional opportunity for photosynthetic activity afforded the trees by the addition of 218 hours to the working time of the first four months is reflected in the large number of varieties having their maximum sugar content in that year.

The conditions prevailing during the period of maturity, namely, normal temperature and reduced sunshine, appear to have been conducive to the reduction of astringent nontannins to a low level, possibly by hydrolysis of glucosides and setting free sugar. In consequence, while true tannins were at the maximum level, nontannins were rather low, and relative total astringency was at the minimum.

That enzymic activity was relatively vigorous during the period of maturation is indicated by the fact that the samples of juice were as a group remarkably free of starch, as shown by the negative results of examination of the fresh juices as well as by the results of analyses of unfiltered Pasteurized samples. As compared with some other years in which starch was present in a considerable number of varieties, this indicates that diastatic activity was initiated earlier, or that it proceeded at a more rapid rate than in those years. Yet the amount of sucrose in the juices of this year were greatly in excess, both relatively and absolutely, of the amounts occurring in any other year for most of the varieties.

The acid content, while next o maximum in average amount, is materially below that of the maximum year both in absolute amounts and in comparative numbers of varieties having maximum amounts in that year. Acidity is apparently not so directly influenced by climatic conditions as are sugars and astringent substances, probably because its amount is due to the intensity of the respiratory process and to the oxygen supply, not to the amount of photosynthetic activity possible nor to the rate of enzymic hydrolysis.

The opposite extreme in chemical composition is observed in 1924, since that year has maximum relative astringency associated with minimum sugar and next to minimum acid contents. Examining the climatological summary (fig. 12), it is seen that the season up

to June 30 had practically normal sunshine (17.5 hours excess) but was notably deficient in heat received (192.2° deficiency), while the remainder of the season had a like condition in sunshine (19.9 hours excess) with a further deficiency of 163.4° in temperature. The deficiency in temperature is very uniformly distributed over the whole growing season as an average deficiency of 1.7° per day. It acts as a brake or limiting factor upon photosynthetic activity, since carbohydrate content is at a minimum despite the excess of hours of sunshine received. The amount of sucrose in the juice is also low, the year ranking fifth in this respect. That the subnormal temperatures also reduced the rate of enzymic activity is indicated by the fact that many of the juices contained traces of starch, as determined by examination and by comparison of total sugars before and after Pasteurization. Such comparison shows that while starch was rather generally present, its amount was not sufficient to affect the ranking of the crop had it been determined and calculated as sugar.

Comparing the two extreme years, 1923 and 1924, it is found that their outstanding climatic differences consist in the reception in the first four months of the growing season of 1923 of 200.6 hours more sunshine and of 372.7° more heat than were received in the corresponding period in 1924. In the last three months 1924 had 86. 5 hours more sunshine but 180.6° less heat than 1923. There was also a difference of 14.9 inches in rainfall, 1923 having a deficiency for the season of 4.78 inches, while 1923 had an excess of 10.12 inches; but there is scarcely a possibility that precipitation figured directly in the results. The large differences in the two crops must be attributed to the large differences in conditions for photosynthetic activity in the two seasons.

The year 1921 stands next after 1923 in point of sugar content, while it ranks first in total titratable acidity. The departures from the mean in climatic conditions consist in excesses of 80.9 and 15.9 hours of sunshine and of 585.5° and 213.9° of heat received in the first four and the last three months of the season, respectively. The excess of sunshine is materially less than that of 1923, but is accompanied by very much higher temperatures (nearly 5° per day excess). The two factors together are decidedly favorable to photosynthetic activity, raising the carbohydrate content of the fruit to a level second only to that attained in the less warm but phenomenally sunny season of 1923. In amount of sucrose present in the juice the year ranks second to 1923, but the amounts present were relatively and absolutely considerably below those found in that year.

The high carbohydrate content of the crop of 1921 is attributable to the seasonal conditions, the reduction in the size of the crop playing only a minor and insignificant rôle. This conclusion is stated with greater confidence by reason of the fact that the writer has reached it despite a preconceived opinion to the contrary. The crop upon many varieties was wholly destroyed or greatly reduced by frost. The possibility that the results might be vitiated by inclusion in the analyses of the fruit from trees markedly subnormal in crop was clearly in mind, and the varieties analyzed were restricted to those having 65 to 100 per cent of a full crop, as determined by persons familiar with the varieties concerned. A distinct majority of the varieties employed had crops equaling 85 per cent of the normal,

and only a relatively small proportion of the total number had crops falling between 65 and 75 per cent of full crop. Careful notes of yield of the individual varieties were made at the time of picking, and these notes have been exhaustively compared with the analytical data in an attempt to ascertain whether the varieties having a reduced load of fruit, as a group, show higher sugar content than the group having crops of normal or approximately normal size. No conclusive evidence of such differences can be found in any case in which the fruit on the tree equaled 75 per cent of normal, and such effects are not clearly or constantly present in those having the crop reduced below this level. That this is true is convincingly shown by the fact that exclusion from consideration of all varieties having less than 85 per cent of a full crop does not alter the rank of 1921 as to sugar content and makes only very insignificant changes in the percentages of the total number falling into first, second, and third places in respect to their sugar content.

This situation was exactly opposite to expectation and apparently in contradiction to prevalent conceptions as to the effects of thinning upon quality of crop. The explanation seems to lie in the differences between thinning due to frost and that performed by human agency. In the present case, as shown by the orchard notes, the frost injury was confined in most instances to the tops and northwest sides of the trees. On these portions there was usually only an occasional fruit, while the lower branches and the leeward side were fully loaded, only the central flower of most clusters having been killed. That a barren branch makes little or no contribution to the development of the fruit on other and distant portions of the tree is fairly well known. Consequently the effects of frost in this instance have nothing in common with the equalized distribution of fruit over the tree which it is the purpose of thinning to accomplish. From these facts, and from the results of repeated and detailed examination of the data, the writer is convinced, contrary to his preconceived opinion, that the character of the 1921 crop was due to seasonal conditions without perceptible influence from frost thinning.

It is worthy of note that high acidity accompanies high sugar content in the years of high sunshine and high temperatures, 1923 and 1921, while minimum acidity accompanies minimum sugar in 1924, the year of markedly subnormal temperatures. The matter of acidity in relation to temperature will be referred to again in discussing the 1925 results.

The year 1920 has been commented upon as presenting an exceptionally close approximation to the normal or 50-year average in the distribution and amount of its climatic factors. It is fifth of the six years in point of sugar content and fourth in acidity. That it ranks so low may at first thought be surprising in view of its normal character. But it does not necessarily follow that the normal climatic conditions in the latitude of Washington are conducive to optimum development of apple fruits or to storage of a high content of sugar therein. It seems clear that the year is inferior in this respect to four of the five less normal years with which it is here compared. This must mean that in so far as photosynthetic activity as measured by the storage of sugar in apple fruits is concerned, a considerable increase above normal in hours of sunshine, as in 1923 and 1924, or in total temperature units received, as in 1922, or in both together, as in

1921, can be advantageously utilized by trees. It must mean also that the rainfall is considerably in excess of the minimum required by the trees, since considerable reduction in its amount, but not in its distribution, occurs in years showing higher sugar content than the normal. In other words, each of these factors has a value in the normal year considerably removed from the value at which it becomes a limiting factor, precipitation being considerably above, sunlight and temperature considerably below, the limiting values. Consequently, the fluctuations which have occurred in the amounts of these factors in four out of six years have been such as to favor greater storage of sugar; in one year only have they been such as to result in decreased sugar storage in the fruit.

It is especially unfortunate that data upon astringent constituents were not obtained, as it would be of decided interest to know the quantity of these constituents in a year conspicuous for the absence of outstanding departures from normal averages on the part of any climatic factor, as was 1920. That the crop as a whole contained the minimum amount of sucrose found in any year would indicate that the attainment of a high ratio of sucrose to total sugar in the fruit requires conditions not normally occurring at Washington.

The year 1922 is marked by its absence of extremes in the composition of the crop. In sugar content it stands fourth; in acid content third; in relative astringency it is second. The climatic conditions are in instructive contrast to those of 1920; 1922 had subnormal sunshine, 48.7 hours less than 1920, between March 1 and June 30, but this subnormal amount was associated with above-normal temperature as against subnormal in 1920. The difference between the two years is 378.5° for the four months, or more than 3° daily. The temperatures and hours of sunshine for the period subsequent to July 1 were almost identical for the two years, being very close to the normal. It would appear that the higher sugar content in 1922 must be attributed to the effect of the large additional number of heat units received despite the smaller number of hours of sunshine. Nontannins were maximum in amount (Table 6), pointing to a moderate rate of destruction under the normal temperatures prevailing during the last part of the growing season, and relative astringency ranks next to maximum by reason of the occurrence together of medium sugar and acid content and high astringent nontannins.

The year 1925 gave a crop showing a combination of chemical characters not elsewhere found during the period covered by the work. It is third in total sugar content, sixth in acid, and third in relative astringency. The crop was consequently lower in acid and astringency and higher in sugar than that of 1922, while higher in sugar, a little lower in acid, and much lower in astringency than that of 1924. The results, therefore, are in contradiction to those of these years and to the general situation found in all the other years, which is that of high sugar combined with low astringency or the reverse.

The seasonal conditions in the period from March 1 to June 30 present a combination of an excess of sunshine (151.8 hours) exceeded only in 1923 with a very considerable excess of heat (280.7°). The temperature excess approaches that of 1922, while the sunshine was 175.3 hours greater than in that year. If these factors alone determine the amount of photosynthetic activity, the sugar content

of the 1925 crop should be much greater than that of 1922 and should closely approach that of 1923. Instead it ranks only slightly above 1922 and very decidedly below 1923. The year 1925 had in the growing season 134.3 hours more sunshine and 472.9° more heat than 1924 and it had 126.6 hours more sunshine and 352.5° more heat than 1920, which should rank 1925 far above both and should show a large number of varieties attaining maximum sugar content. While 1925 does stand considerably above 1924 in this respect, it has percentages of maximum and next to maximum results only very slightly greater than 1920.

In the conditions subsequent to July 1, 1925 had a deficiency of sunshine almost identical in amount with that of 1923, with an excess of temperature over that year of 77.4° due to very high September temperatures. Such a combination can not be considered as responsible for the low sugar content, since the conditions of this period in 1923 were even less favorable for photosynthetic work, yet 1923 is the year of maximum sugar content.

These considerations force one to the conclusion that with respect to sugar content, 1925 stands one or two places below the rank in which the amount of sunshine and heat received would place it, and that photosynthetic efficiency has been considerably reduced by the operation of a limiting factor. That deficient rainfall may have been such a factor is at once suggested by inspection of Figure 12 and is very strongly indicated by Figures 9 and 8. The deficiency was not only greater in amount than in any other year, but it was so distributed as to exert maximum effect upon the crop. The shortage on March 1 was larger than in any other year, and the precipitation between March 1 and June 30 was less than half the normal, so that the total received during the winter and up to July 1 was only 1.77 inches more than the normal up to March 1. The crop began its development with a shortage of 5.45 inches, which mounted steadily to 13.32 at the end of July, then more slowly to 15.20 at the end of the season. The cumulative shortage approached its maximum in June, which was the hottest month of the year, with a mean temperature equaled in the records for Washington only by that of 1878, and with a large excess of sunshine (74 per cent of the possible instead of the normal 62). There was general evidence of suffering from water shortage on the part of farm crops in the plots surrounding the orchard and in the annuals growing in the orchard itself during the month of June, and flagging and incipient wilting of the foliage of the apple trees was often apparent. There is little doubt that partial or complete closure of the stomata with corresponding reduction or suspension of photosynthesis was of frequent occurrence during the period and possibly also in the excessively hot days of late May and early July. In consequence, the storage of sugar in the crop was reduced in an unmistakable degree below that which would have been possible with an adequate water supply.

Acid content reached the minimum for the whole period in 1925, while relative astringency was next to minimum for the 4-year period for which data were obtainable. The combination of low acidity and low astringency has not been encountered elsewhere in the series. Barss (*6*) has shown that in the case of the Bartlett pear, growth of the crop with an extremely limited water supply results in extremely marked and unpleasant astringency, and the writer has

observed that peaches grown without irrigation in the vicinity of Tucson, Ariz., are so astringent as to be almost inedible even when soft ripe. If a similar effect is produced in the apple, it occurs only when the deficiency of water is greater than was the case here or when other conditions are materially unlike those here encountered.

The low acidities of 1924 and 1920 occur in cool seasons in which the maturing of the fruit, as measured by its softening to cider ripeness after picking, was a rather slow process. The 1924 crop is also one characterized by high astringency. The situation in 1925 differs from that of these and other years in that the temperature during September was abnormally high, exceeding the mean by 4.7° daily, while that of October was abnormally low, the daily deficiency equaling 5.3°. (Fig. 8.) The transition from the mean temperature of 72.8° F. for September to 52° for October is in decided contrast with the normal change from 68.1° to 57.3°. The high temperatures of September accelerated maturity changes, so that picking occurred somewhat early in the case of many varieties. In the case of early varieties, softening went on rapidly after picking, and fruit could be held for only very short periods before it reached pressing ripeness. The later maturing varieties were similarly affected by September conditions, beginning to soften either on the trees or in storage, but as the cooler October weather came on there was a marked slowing down in rate of softening. This was especially evident in fruit held in a basement room after picking, many varieties showing very little or no change in firmness, as measured by a puncture test, during 10 to 15 days. The effect of the high temperatures of September was undoubtedly to accelerate respiration and enzymic processes, such as starch conversion and the splitting of glucosides. With the large alteration of temperature which occurred near the beginning of October, these processes were greatly slowed concurrently with the slowing down of softening of the tissues.

The change occurring under these conditions was somewhat like that which may be produced by placing fruit in cool storage. That some such effect would follow was anticipated, and quantities of 10 varieties were placed in a basement room and sampled at intervals of about 10 days during late October and early November. The results, presented in Table 14, show quite clearly what happened. Titratable acidity is rather low at the first sampling, rises somewhat, then drops rather rapidly. Starch conversion goes on rapidly at first, then much more slowly. Nontannin astringency decreased irregularly, but rather more rapidly at the outset than later. It had already reached a rather low point before storage. The effect of the incipient softening of the tissues in some way increased the subsequent rate of disappearance of acid, probably by increasing the permeability of the tissues to oxygen. Magness and Burroughs (*27*) found that high respiratory rate reduced acid content much more rapidly than sugar. The general behavior of these lots of fruit is that of fruit allowed to become overripe before picking and placing in storage. The rapid changes initiated in the fruit while still on the trees were somewhat slowed down, but not to the degree which would have occurred in a year having less marked departures from the normal temperature curve.

TABLE 14.—*Results of repeated analyses at short intervals of fruit held in common storage, October and November, 1925*

Variety	Date picked	Date analyzed	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar	Acid	Total astringency	Tannin	Nontannin	Solids
Akin	Oct. 15	Oct. 22	7.05	2.63	9.68	0.260	0.1055	0.0502	0.0553	11.79
		Oct. 31	8.48	2.80	11.28	.314	.0772	.0212	.0560	13.56
		Nov. 10	9.00	2.76	11.76	.268	.1062	.0383	.0679	13.56
		Nov. 20	8.64	2.57	11.21	.230	.1011	.0342	.0669	12.84
Baldwin	do	Oct. 22	4.66	2.94	7.60	.268	.0740	.0177	.0563	10.06
		Nov. 2	7.33	3.12	10.45	.390	.0900	.0373	.0527	12.74
		Nov. 10	7.03	2.80	9.83	.351	.0940	.0420	.0520	11.32
		Nov. 21	6.84	2.79	9.63	.314	.0876	.0364	.0512	10.96
Ben Hur	Oct. 10	Oct. 22	5.34	2.29	7.63	.188	.0537	.0147	.0390	10.13
		Nov. 2	7.35	2.99	10.34	.196	.0832	.0357	.0475	12.49
		Nov. 10	7.11	2.69	9.80	.173	.0710	.0294	.0416	11.96
Hort. No. 3050	Oct. 16	Oct. 21	8.37	1.52	9.89	.292	.1440	.0512	.0928	12.75
		Oct. 31	9.68	1.76	11.44	.242	.1260	.0495	.0765	14.70
		Nov. 9	9.40	1.46	10.86	.260	.1140	.0255	.0885	14.34
Keeper	Oct. 10	Oct. 22	5.98	2.82	8.80	.334	.0366	.0066	.0300	9.67
		Nov. 2	7.42	2.62	10.04	.380	.0495	.0095	.0400	12.07
		Nov. 15	6.94	2.39	9.33	.331	.0408	.0058	.0350	11.69
Kinnard	Oct. 3	Oct. 7	5.76	2.66	8.42	.404	.0835	.0360	.0475	10.43
		Oct. 22	6.36	1.96	8.32	.280	.1062	.0432	.0630	10.22
		Oct. 31	7.54	2.09	9.63	.314	.0899	.0302	.0597	12.19
		Nov. 10	6.86	1.62	8.48	.260	.1062	.0438	.0624	10.80
Santa	Oct. 16	Oct. 22	6.48	2.61	9.09	.710	.0950	.0380	.0570	11.69
		Oct. 31	6.66	2.92	9.58	.628	.0722	.0230	.0492	13.18
		Nov. 9	6.19	2.53	8.72	.645	.0892	.0272	.0620	10.61
Shone	Oct. 3	Oct. 21	8.44	2.49	10.93	.292	.0485	.0120	.0365	13.01
		Oct. 31	8.78	2.72	11.50	.374	.0638	.0188	.0450	13.76
		Nov. 9	8.44	2.50	10.94	.378	.0706	.0289	.0417	12.86
		Nov. 18	8.23	2.18	10.41	.331	.0674	.0266	.0408	12.67
Sweet Orange	Oct. 10	Oct. 22	7.54	3.45	10.99	.150	.0895	.0257	.0638	12.21
		Nov. 2	10.16	3.65	13.81	.166	.1110	.0370	.0740	16.63
		Nov. 19	9.83	3.61	13.44	.141	.1011	.0383	.0628	16.41
Winter Paradise	do	Oct. 21	8.70	1.76	10.46	.104	.1699	.0650	.1049	12.45
		Oct. 31	9.32	2.16	11.48	.092	.1620	.0670	.0950	13.84
		Nov. 9	8.62	1.89	10.51	.078	.1530	.0710	.0820	12.88

Until much more is known as to the nature of the astringent materials and the character of the changes that they undergo during the maturation of the fruit, it is impossible to offer anything more than a tentative explanation of the fact that high sugar and acid content are correlated with low relative astringency, or the reverse. The present study yields some data toward the formation of such an explanation. A considerable portion of the material included in the astringent nontannins consists of flavones and related compounds, chiefly glucosidal in nature. These are greatest in amount in the immature fruit and gradually decrease as maturity proceeds. The processes responsible for the decrease are in part hydrolysis and in part physical combinations with pectins as these are brought into solution from the cell walls. Temperature controls the rate of both these processes, determining the rate of the hydrolysis of glucosides and also the rate of solution of pectins. The presence of oxygen is not necessary for either process. High temperatures during the ripening of the fruit appear to be definitely associated with low astringency, as in 1923

and 1925, and low temperatures in this period with high astringency, as in 1922 and 1924. It has already been noted that the amount of starch present in the fruit at the stage of cider ripeness is greater in years having low temperatures during the ripening period. This would indicate that diastase is less abundant or less active in the cooler seasons. If it be true that temperature controls the rate of these enzymic processes, the presence of starch and of high astringent content in the years of lower temperatures in the ripening period, and the absence of starch and reduction of astringent substances to a low level in the years of warm harvest seasons, are thereby explained.

GENERAL DISCUSSION

It has been shown in the discussion of the analytical data that, in the apple, sugar content is rather definitely and consistently correlated with acidity and astringency, positively with acidity, negatively with astringency, so that high sugar and high acid are accompanied by low astringency, and low sugar and low acid by high astringency. These correlations break down only under the exceptional condition that a climatic factor is so far altered in amount that it becomes limiting and thereby alters the course of some physiological process while permitting others to go on unaltered or possibly accelerated. Such exceptional conditions were encountered in 1925, but with the exception of this year the correlations just stated hold quite well for the large group of varieties here considered, which purposely includes fruits showing as wide range in character as it was possible to obtain.

It must be emphasized that the correlation here stated is not to be understood as a hard-and-fast rule which will apply without exception to individual varieties selected at random from the analytical tables. It is not of this character, and any attempt so to apply it will encounter numerous individual cases in which it does not hold. The conception which is intended to be conveyed by the statement that high sugar, high acidity, and low astringency are associated, and that low sugar, low acidity, and high astringency are also found together, is the conception that in a broad way these chemical situations are apparent when a large group of varieties are considered en masse. The climatic factors operating upon the developing crop are exerting an effect upon the quantities of these three constituents which will be evident when the crop is analyzed at any given moment of its maturity. The conditions which make for attainment of high sugar content are those which make for retention of acidity at a high level and also those which make for reduction of astringent materials to a low level. Conversely, the conditions which tend to hold the sugar content to a low level exert a like effect upon acid content, while tending to leave astringency at a high level.

These effects will be apparent as mass tendencies when the data for a large number of varieties are collectively examined, and the direction and extent of the mass movement will be found to be controlled by the character of the environmental complex. But the individual varieties will not all exhibit the same tendencies or exhibit them to an equal degree, for two reasons. In experiments in which all the conditions are as carefully controlled as is possible, a group of apparently identical plants of the same species or variety show individual variations to an extent which makes it necessary to work with large

numbers and obtain average results. In the present work a great diversity of uncontrolled conditions exists. Differences of soil texture and moisture content, exposure to sun, age, physical vigor, freedom from disease, and fruiting habits of trees are some of the factors which are not controlled. That the response to any given condition on the part of such an assemblage will not be unanimous in character or amount is certain, because of the great variety of these unmeasured differences between individuals. It is precisely because such a heterogeneous assemblage of plant forms behaves in such large degree as one in its response to differences in the seasonal conditions that one may feel confident that he is dealing with a general and fundamental fact with respect to the response of plants to the environment. The response of the occasional individual may be modified or suppressed by conditions peculiar to itself, but the response of the group as a whole may safely be taken as the expression of a truth.

As has been pointed out by the writer, in discussing the results of his work upon grapes (*11*), the composition of a fruit at maturity is the resultant of a series of interrelated physiological processes. Climatic conditions may influence two of these processes in the same direction, but not to the same degree, since each process is conditioned as to its rate by other factors. Nor will the progress of any one process in two different plants or fruits necessarily be identical, since it is in some degree affected by internal conditions peculiar to the individual. Consequently it is not to be expected that high sugar content is in all cases to be found associated with low astringency, but rather that this will be so frequently the result that we are forced to the conviction that the conditions which produce the one result are also in the main productive of the other.

It is to a very considerable extent true that individual varieties show the same correlations between acid, tannin, and sugar that have been shown to hold for groups of varieties. The analyses of Shaw (*30*) show a fairly consistent correlation between acid and sugar content, which are high or low together. When it is considered that Shaw's samples were collected at widely separated points and by various individuals, subjected to widely varying conditions during transmission to Amherst, and analyzed at various stages of maturity, it is rather surprising that the relation of acid to sugar was as consistent as the figures show it to be. Unfortunately, no determinations of astringent constituents were made. Jones and Colver (*22*) made a very extensive series of analyses of apples and other fruits grown in Idaho. The primary purpose of their work was to ascertain whether there are constant differences of composition between fruits of the same variety when grown on irrigated and nonirrigated soils. The samples analyzed were collected from all sections of the State, the accompanying data relating only to the irrigation or absence of irrigation of the trees. Under the conditions there was necessarily considerable variation in the handling and treatment of the material and consequently in the condition of the various samples, although all were characterized as fresh ripe at the time of analysis. An examination of the results of these investigators is nevertheless of considerable interest. They analyzed 284 samples of 17 standard varieties, the number of samples of a variety ranging from 3 to 79. The samples were collected in 1909, 1910, and 1911. There is throughout their work a quite consistent association of high sugar

content with high acidity and of medium or low sugar with medium to low acidity, in both irrigated and nonirrigated fruits. The absolute maxima occur together in a number of cases, as do absolute minima, and the two constituents take rank near together in all but a small number of cases.

Jones and Colver did not make determinations of tannins and astringent materials, and it has not been possible to find in the literature any series of analyses which would throw light upon the relation of these constituents to acidity and sugar content. Bigelow, Gore, and Howard (*8*), Alwood, Davidson, and Moncure (*4*), and others who have made determinations upon tannin in connection with ripening processes or in other studies, do not have data with a bearing upon the point here under consideration.

In his work on the effects of climatic conditions upon the chemical composition of grapes, the writer found a rather clear-cut and consistent correlation of a different type. The nearness of the ocean has a stablizing effect upon summer temperatures at Vineland, N. J., where the work with grapes was carried on, with the result that the amount of sunshine received during the growing season was the only climatic factor showing large annual variations during the period of the work. The sugar content of the crop varied with the amount of sunshine received, being highest in the year of maximum sunshine and decreasing with decrease in the amount of that factor. Acid and astringent content were correlated with sugar content, but in such fashion that high sugar was accompanied by low acid and astringency, and low sugar by high acid and astringency. In the grape, acid and astringent content take rank together, always in opposition to sugar content; in the apple, sugar and acid take rank together in opposition to astringency content. In the grape, the total astringency, that is, the absolute amount of astringent materials, varies in the manner stated; in the apple it is not the absolute but the relative total astringency, that is, the amount of astringent material considered in its relation to sugar and acid content, which varies in this way.

The unlikeness of the results with respect to acidity in the apple and the grape is to be anticipated in view of the work of Alwood (*2*, *3*) on the changes in acidity in grapes during ripening. In the grape, the acid of the immature berry is rather sharply localized in two areas, one about the seeds, the other a zone of pulp immediately beneath the skin, as Hedrick (*20*) has shown. During the ripening process, conversion of the acid of the peripheral layer into tartrates occurs, the disintegrating pulp becoming filled with tartrate crystals (*2*). In a number of varieties studied by Alwood, the titratable acidity of the juice was reduced during the ripening period to less than half that present at its beginning (*3*). Disintegration of the peripheral zone of pulp facilitates tartrate formation by permitting contact of the reacting substances, and the rate at which this disintegration occurs is determined by the climatic conditions of the ripening period. High temperatures and continuous sunshine consequently favor reduction of titratable astringency through accelerating formation of acid salts. In the apple there is no comparable transformation of acids during ripening.

In the grape the materials contributing to total astringency are, except in occasional nonpigmented varieties, mainly nontannins, that is, coloring matters, glucosides, and other substances oxidiz-

able by potassium permanganate but not precipitable with gelatin. In consequence, whether total astringency in any given grape shall be high or low is determined by the amount of astringent nontannins present, the proportion borne by the true tannins to the total being too small to affect materially its amount. In the apple the amount of true tannin in relation to the total astringent material present is usually much larger than in grapes, and in many varieties it makes up the larger part of the total.

Tannin fluctuates considerably in amount in the apple from year to year, apparently as a variable not directly affected by the amount of any other constituent, and these fluctuations affect the sum total of astringents much more than is the case in the grape. The result is that absolute amounts of astringents are as often determined by the tannin as by the nontannin fraction. Nevertheless, relative astringency, that is, the ratio borne by the amount of astringent substances to sugar content, exhibits the same correlation with sugar and acid found for total astringents in the grape.

It has been stated above that tannin content in the apple appears to be a variable. The quantity present in the fruit of any variety of apple from year to year appears to fluctuate without discernible relation to the intensity or distribution of any factor of the environment. During the preparation of this paper the writer has examined the data of his previously published paper upon grapes, and is convinced that tannin content in the grape is also an independent variable.

It would appear, therefore, to be a tenable conclusion that the seasonal amount and distribution of the climatic factors sunshine, temperature, and precipitation affect the composition of the crop borne by apple trees grown under controlled conditions in definite and consistent fashion. That the response to variations in amount of these factors is a fundamental physiological one is evidenced by the fact that a group of 216 varieties, in which apples of the greatest obtainable diversity in type and character were purposely included, shows a definite mass behavior or tendency to behave as a unit through six successive years. This mass behavior exhibits a definite relation to the variations in climatic conditions during the growing season. That the response is a fundamental response of the plant mechanism to the conditions of the environment is further shown by the fact that under like seasonal conditions the apple and the grape show like modifications in chemical composition. The two fruits exhibit the same correlation between the changes in amount of their constituents, with minor differences attributable to their structural and physiological dissimilarity.

GENERAL SUMMARY

The apple variety collection of the Bureau of Plant Industry at the Arlington Experiment Farm, Rosslyn, Va., near Washington, D. C., has been employed in a study of the variations in chemical composition of the expressed juices occurring from year to year and the relations borne to such variations by the annual variation in climatic conditions. The trees received uniform cultural treatment during the six years of the work (1920–1925). Of the varieties included in the experiment at its beginning, 216 fruited with a sufficient degree of regularity to permit inclusion of the data in the

results. These 216 varieties include apples of the widest diversity in character of fruit and adaptation to locality possible to procure in the collection.

The six years during which the work was in progress presented an exceptionally wide range both in the amounts and distribution of the individual climatic factors and in the combinations of these factors occurring during the growing season at Washington. The year 1920 was remarkable for the close approximation to the 50-year average in the amount and distribution of the three climatic factors, sunshine, temperature, and precipitation; 1921 was an exceptionally warm year, receiving 799.4° excess temperature in the period from March 1 to September 30, with a considerable excess of sunshine; 1922 had a considerable excess of temperature and of precipitation, with less than normal sunshine; 1923 had a very large excess of sunshine, rather high temperature, and subnormal rainfall; 1924 was markedly subnormal in temperature, had a large excess of precipitation, and a little more than normal sunshine; 1925 was excessively dry with consistently above-normal temperatures and considerably more than normal sunshine.

The chemical composition of the crop of a given year, when the results for all varieties are considered collectively, shows a definite relationship to the amount and distribution of the climatic factors during the growing season of that year. These climatic factors exert an effect upon chemical composition which manifests itself as modification in like direction and degree of the composition of the fruit of a large number of varieties of widely diverse character and degree of adaptation to locality.

Of the three climatic factors, sunshine, temperature, and precipitation, variations in amounts of sunshine and temperature, within the limits encountered in this work, are most effective in determining the chemical composition of the crop at Washington, D. C. The fact that the amounts of sunshine and heat received departed from the normal in the same direction in three years and in opposite directions in the remaining three permits an approximate relative evaluation of their separate effects. Variations from normal in amount of sunshine received during the growing season are productive of largest effect; variations in amount of heat received are less effective, within the limits encountered in this work. Precipitation may depart very considerably in either direction from the normal at Washington without discoverable effect upon the crop. The amount and distribution of rainfall is a significant factor in determining the composition of the crop in one year only of the six years covered by the work.

If the composition of the crop in 1920, a year very closely approximating the normal in climatic conditions, is used as a basis for comparison, the relation of climatic conditions to chemical composition of apples at Washington is such that increases in amount of sunshine and temperature over the 50-year average or normal amounts result in general increases in sugar content of the fruit over the amount present in the climatically normal year. Decreases in amounts of sunshine and temperature below the 50-year average result in general depression of sugar content of the fruit below the amount present in the climatically normal year. The extent of the departure of sunshine and temperature from the normal amounts is a direct measure

of the departure of the composition of the crop from that of the climatically normal year in every year except 1925. In that year, a large deficiency in precipitation operated as a limiting factor upon photosynthesis and altered the degree but not the direction of the response of the crop.

There is a definite and consistent correlation of sugar content, both of total sugar and of sucrose, with acid content and content of astringent substances. The correlation between sugar content and acidity is positive, that between sugar and astringent substances is negative, high sugar content being accompanied by high acidity and low astringency, low sugar content by low acidity and high astringency, and medium sugar content by absence of extremes in amounts of the other two constituents. This general relationship of sugar, acid, and astringent content is consistently presented by masses of varieties. In one year the correlation breaks down as a result of the interference of a limiting factor, shortage of water, with the normal course of physiological processes.

The correlation between sugar, acidity, and astringent content just stated is not an absolute and rigid rule, applying without exception to individual varieties under the conditions of the experiment. There are a large number of known and unknown conditions, such as local differences in soil, water supply, exposure, individual or varietal fruiting habit, susceptibility to disease, and others which can not be measured or brought under control in large-scale field experiments of this character, and which produce a considerable number of individual exceptions. That the correlation is a mass phenomenon consistently exhibited over a series of years despite the effect of these uncontrolled factors is conclusive evidence of its fundamental character.

The climatic conditions conducive to the development of a high content of sugar and acid in the fruit of the apple are also conducive to the reduction to a low level of the content of astringent materials therein. Conversely, the climatic conditions which limit the development of sugar and acid content to a medium or low level are such as increase the formation, or depress the rate of destruction, of astringent substances, thus leaving their amount at a higher level. As a result, absence of extremes, as medium sugar and medium astringency, or opposite extremes, as high sugar and low astringency or the reverse condition, are found together. Like extremes, as low sugar and low astringency, are not found together, for the reason that any one set of climatic conditions can not produce both results. In consequence, the acid-astringency-sugar ratio of a given variety will vary quite widely from year to year in a locality having as wide variation in seasonal conditions as Washington, and will have relatively narrow variations in a region having a narrow range of variation in seasonal conditions.

The acid-astringency-sugar ratio, which states the relative amounts of titratable acidity, total sugars, and total astringent substances contained in a fruit juice, presents the results of chemical analysis in a form designed to convey a conception of the beverage quality of the juice. The ratio expresses the relative amounts of the three factors upon which the sense of taste bases its estimate of the product. Since beverage quality depends upon the relation rather than the absolute amounts of these substances, a knowledge of the acid-

astringency-sugar ratio is more important than a chemical analysis in determining the beverage quality of a juice.

It has now been established that climatic conditions during the growing season exert a determining influence upon chemical composition of the annual crop of fruit in the case of two perennial plants, the apple and the grape, and that the character of the effect upon the various constituents of the fruit is identical except for secondary differences due to morphological dissimilarities of the two fruits. Since large groups of dissimilar varieties of the two species exhibit uniformity of response to the annual variations in the factors of the climatic complex, it would appear that the annual crop of fruit upon a perennial plant is an integrated expression of the climatic factors for the season in which it is produced, in the same degree to which the growth of an annual plant integrates these factors.

LITERATURE CITED

(1) ABBE, C.
1905. A FIRST REPORT ON THE RELATIONS BETWEEN CLIMATES AND CROPS. U. S. Dept. Agr., Weather Bur. Bul. 36, 386 p.

(2) ALWOOD, W. B.
1911. ENOLOGICAL STUDIES. THE SUGAR AND ACID CONTENT OF DIFFERENT VARIETIES OF GRAPES, SAMPLED AT FREQUENT INTERVALS DURING RIPENING AND AT FULL MATURITY. U. S. Dept. Agr., Bur. Chem. Bul. 140: 16–24.

(3) ———
1914. CRYSTALLIZATION OF CREAM OF TARTAR IN THE FRUIT OF GRAPES. Jour. Agr. Research 1: 513–514.

(4) ——— DAVIDSON, W. J., and MONCURE, W. A. P.
1904. CHEMICAL COMPOSITION OF APPLES AND CIDER. U. S. Dept. Agr., Bur. Chem. Bul. 88, 46 p.

(5) ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS.
1920. OFFICIAL AND TENTATIVE METHODS OF ANALYSIS. AS COMPILED BY THE COMMITTEE ON REVISION OF METHODS. REVISED TO NOV. 1, 1919. 417 p., illus. Washington, D. C.

(6) BARSS, A. F.
1915. THE PEAR AS AFFECTED BY MOISTURE SUPPLY. Oreg. Agr. Expt. Sta. Bien. Crop Pest and Hort. Rpt. (1913/14) 2: 38–49, illus.

(7) BEACH, S. A., BOOTH, N. O., and TAYLOR, O. M.
1905. THE APPLES OF NEW YORK. 2 v., illus. New York.

(8) BIGELOW, W. D., GORE, H. C., and HOWARD, B. J.
1905. STUDIES ON APPLES. I. STORAGE, RESPIRATION, AND GROWTH. U. S. Dept. Agr., Bur. Chem. Bul. 94: 1–67, illus.

(9) BUNYARD, E. A.
1920. A HANDBOOK OF HARDY FRUITS MORE COMMONLY GROWN IN GREAT BRITAIN. APPLES AND PEARS. 204 p., illus. London.

(10) CALDWELL, J. S.
1922. STUDIES IN THE CLARIFICATION OF UNFERMENTED FRUIT JUICES. U. S. Dept. Agr. Bul. 1025, 30 p.

(11) ———
1925. SOME EFFECTS OF SEASONAL CONDITIONS UPON THE CHEMICAL COMPOSITION OF AMERICAN GRAPE JUICES. Jour. Agr. Research 30: 1133–1176, illus.

(12) ———
1928. MEAN SUMMER OR "OPTIMUM" TEMPERATURES IN RELATION TO CHEMICAL COMPOSITION IN THE APPLE. Jour. Agr. Research, 36: 367–389.

(13) CANDOLLE, A. DE
1855. GÉOGRAPHIE BOTANIQUE RAISONNÉE. 2 v., illus. Paris.

(14) CHANDLER, W. H.
1925. FRUIT GROWING. 770 p., illus. Boston, New York [etc.].

(15) DUGGAR, B. M.
1911. PLANT PHYSIOLOGY, WITH SPECIAL REFERENCE TO PLANT PRODUCTION. 516 p., illus. New York.

(16) GANTTNER, F.
1889. DIE BESTIMMUNG DES GERBSTOFFES MIT CHAMÄLEON. Ztschr. Angew. Chem. 1889: 577–580.
(17) GARDNER, V. R., BRADFORD, F. C., and HOOKER, H. D.
1922. THE FUNDAMENTALS OF FRUIT PRODUCTION. 686 p., illus. New York.
(18) GOURLEY, J. H.
1917. SOME OBSERVATIONS ON THE GROWTH OF APPLE TREES. N. H. Agr. Expt. Sta. Tech. Bul. 12, 38 p., illus.
(19) HABERLANDT, F.
1874. DIE OBEREN UND UNTEREN TEMPERATURGRENZEN FÜR DIE KEIMUNG DER WICHTIGEREN LANDWIRTHSCHAFTLICHEN SÄMEREIEN. Landw. Vers. Sta. 17: 104–116.
(20) HEDRICK, U. P.
1919. MANUAL OF AMERICAN GRAPE-GROWING. 458 p., illus. New York.
(21) HOWARD, W. L.
1915. AN EXPERIMENTAL STUDY OF THE REST PERIOD IN PLANTS. FIFTH REPORT. Mo. Agr. Expt. Sta. Research Bul. 21, 72 p., illus.
(22) JONES, J. S., and COLVER, C. W.
1912. THE COMPOSITION OF IRRIGATED AND NON-IRRIGATED FRUITS. Idaho Agr. Expt. Sta. Bul. 75, 53 p.
(23) KELHOFER, W.
1908. BEITRÄGE ZUR KENNTNIS DES BIRNGERBSTOFFS UND SEINER VERÄNDERUNGEN BEI DER OBSTWEINBEREITUNG. Landw. Jahrb. Schweiz 22: 343–410, illus.
(24) LIVINGSTON, B. E.
1916. PHYSIOLOGICAL TEMPERATURE INDICES FOR THE STUDY OF PLANT GROWTH IN RELATION TO CLIMATIC CONDITIONS. Physiol. Researches 1: 399–420.
(25) ——— and LIVINGSTON, G. J.
1913. TEMPERATURE COEFFICIENTS IN PLANT GEOGRAPHY AND CLIMATOLOGY. Bot. Gaz. 56: 349–375.
(26) MCLEAN, F. T.
1917. A PRELIMINARY STUDY OF CLIMATIC CONDITIONS IN MARYLAND, AS RELATED TO PLANT GROWTH. Physiol. Researches 2: 129–208.
(27) MAGNESS, J. R., and BURROUGHS, A. M.
[1923]. STUDIES IN APPLE STORAGE. *In* STORAGE INVESTIGATIONS, 1921–1922. Marble Lab. Inc. Rpt. 2: 17–98, illus. Canton, Penn.
(28) MERRIAM, C. H.
1898. LIFE ZONES AND CROP ZONES OF THE UNITED STATES. U. S. Dept. Agr., Bur. Biol. Survey Bul. 10, 79 p., illus.
(29) NEUBAUER, C.
1872. STUDIEN ÜBER DEN ROTHWEIN. Ann. Oenologie 2: 1–41.
(30) SHAW, J. K.
1911. CLIMATIC ADAPTATIONS OF APPLE VARIETIES. Mass. Agr. Expt. Sta. Ann. Rpt. 23: 177–245, illus.
(31) UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.
1920–25. MONTHLY METEOROLOGICAL SUMMARY, WASHINGTON, D. C. Form 1030. Washington, D. C.
(32) ———.
1917–1925. CLIMATOLOGICAL DATA, VIRGINIA SECTION. U. S. Dept. Agr., Weather Bur. Climatol. Data, Va. Sect., vols. 27–35. Richmond, Va.

MEAN SUMMER OR "OPTIMUM" TEMPERATURES IN RELATION TO CHEMICAL COMPOSITION IN THE APPLE[1]

By JOSEPH S. CALDWELL

Physiologist, Office of Horticulture, Bureau of Plant Industry, United States Department of Agriculture

INTRODUCTION

The extent and character of the alterations in chemical composition which the fruits of a given variety of apple may undergo when the trees are grown over a wide range of latitude are very imperfectly known. The relative importance of character of soil, cultural treatment, and climatic conditions in the production of such differences as are observed when comparisons are made between fruits of the same variety grown in widely separated districts is exceedingly difficult to determine, since these factors vary independently in each of the districts under comparison.

The only experimental studies to be found in the literature of the effect on apples of growth under widely varied climatic conditions are those of Shaw (*10*, *11*).[2] The results of his investigations led him to consider summer temperatures as the predominant factor in determining differences in chemical composition of the fruit and resulted in the formulation of the theory that every apple variety has an optimum mean summer temperature at which it attains its best development, departing in a definite manner from such development with departure of the mean temperature from its optimum.

THE OPTIMUM-TEMPERATURE THEORY

Shaw carried on a rather extensive investigation, the results of which are reported in two papers. The first of these (*10*) dealt with the range in form, size, dessert quality, and other characters in the Ben Davis apple in a single orchard, that of the Massachusetts Agricultural Experiment Station, as compared with the variations in these characters found in more than 9,000 specimens obtained from 32 localities representing the entire range of the variety from Quebec to Texas, Arkansas, and California. A progressive alteration in form associated with lessened juiciness, greater astringency, and lower dessert quality was found in the northern-grown samples and was attributed to differences in climatic conditions, temperature being considered the controlling factor. The second paper (*11*) reports the result of extension of the study to include 19 varieties. Samples of these were collected from a number of localities, ranging from 2 or 3 in the case of the less widely grown varieties to 10 to 15 in those of wider distribution, but so chosen as to represent in so far as possible the range of the variety.

[1] Received for publication July 28, 1926; issued April, 1928. This paper is the fourth in a series of studies on fruit juices.

[2] Reference is made by number (italic) to "Literature cited," p. 388.

Ben Davis was represented by 15 samples from 8 States and 3 Canadian Provinces; York Imperial by 8 samples from 6 States; Winesap by 9 samples from 7 States; Baldwin by 11 samples from 6 States; Northern Spy by 10 samples from 7 States and Provinces; Grimes Golden by 11 samples from 7 States and British Columbia; and Jonathan by 10 samples from 8 States and Provinces. The samples were assumed to represent the extent of variation of the varieties to be found throughout the range in which they can be successfully grown. It was further assumed that any particular sample was truly representative of the variety as grown in the latitude from which it came, and that the climatic conditions of the locality and year were in every case typical for the latitude represented by the sample.

The samples were collected by growers in the various places of origin. The samples, ranging from half a dozen fruits to a barrel in quantity, were shipped to Amherst, placed in cold or cellar storage, and analyzed at various times from November to March. The analyses upon the samples of any one variety were made at irregular intervals throughout this period, not all at one time.

The determinations made included total solids, insoluble solids, sucrose, reducing sugars, and acidity. Notes on color and storage and dessert quality were made in some detail. The analytical data are made the basis for formulating several conclusions. These may be briefly summarized:

1. The climatic factor is more potent in producing variation in apples than differences in soils or in cultural treatment.

2. Every variety has an optimum mean summer temperature at which it attains its best development. When grown at either higher or lower temperatures it deteriorates in dessert quality. At lower temperatures the chemical and physical differences are those characteristic of immaturity and include greater acidity and astringency, increased insoluble solids, decreased size and color, and tendency to scalding in storage. Grown at higher temperatures, the fruit is characterized by uneven ripening, premature dropping and rotting on the tree, poor keeping quality, lack of flavor, "mealiness," decreased size, and less intense color. Shaw considered that a difference of 2 degrees or more from the mean optimum temperature in the case of any variety would result in the modification of the fruit in the corresponding direction.

3. The apples on the list of highly successful varieties prepared by the American Pomological Society, with a number of additions, to a total number of 165, are subdivided into 16 groups, to each of which an optimum mean summer temperature (obtained by averaging the monthly means for the seven months March to September) is assigned. These optimum temperatures range from 52° F. for Hibernal, Okabena, and Oldenburg to 67° for Terry and Yates. The largest groups are those with optimum temperatures between 54° and 60°, which have 12 to 20 varieties each.

Shaw's optimum temperature groupings have been widely quoted in textbooks upon fruit growing (*3*, *4*, *5*, *9*). In some of the older books they are made the basis of a recommendation that the grower select varieties for planting with consideration of the relation of their optimum temperatures to the mean summer temperature prevailing in his locality. There is a growing tendency, expressed by Chandler (*3*), to regard the temperature ranges within which optimum development of a variety can occur as somewhat wider than those set by Shaw, but no experimental work has been done since the appearance of his papers.

That the amount of heat received during the growing season, apart from all other factors, can be the only significant factor in

determining the chemical composition of the fruit would appear somewhat questionable. That mean summer temperatures are a very unsatisfactory index of the actual temperature conditions during the season is apparent from a consideration of the methods usually employed in arriving at such means. At most weather stations the daily mean is obtained by halving the sum of the readings of a maximum and minimum thermometer. The sum of such daily means for the entire season, divided by the number of days, is the seasonal mean. Such a figure may be identical for two stations having very different actual conditions. It may be very different from that which would be obtained from averaging hourly temperatures over the same period, and may lead to a quite erroneous idea of the quantity of heat received during the period. In any case the statement of seasonal mean temperature gives no idea of the distribution of the heat received over the period of activity of the plant, and consequently can convey no conception of the part temperature has played in the various phases of vegetative development and production of fruit. It was considerations of this character which led Livingston and Shreve to say (*8, p. 206*):

> Mean temperatures for long periods of time are not apt to be of value in studies of the relations between plant activities and the environment; seasonal or yearly means, which comprise such an important part of the usual meteorological reports, seem never to have given any real promise in this direction. Such means do not take account of the duration factor * * *.

These authors abandoned the use of mean temperatures in favor of the method of physiological indices of temperature efficiency for plant growth as developed by Livingston (*7*) from the work of Lehenbauer (*6*).

In view of the fact that the standard employed by Shaw in classifying the varieties studied by him into temperature groups is itself a variable, it is questionable whether varieties generally are as susceptible to small difference in the amount of heat received during the growing season as he considered them to be. The problem can be successfully solved only under conditions which permit accurate measurement of each of the climatic factors of the environment and control of soil and cultural treatment.

PURPOSE AND METHOD OF THE PRESENT WORK

In the work here reported an attempt has been made to obtain an experimental measure of the effect upon the chemical composition of apples of the differences in climatic conditions occurring over a series of years, the factors of soil and cultural treatment being constant. This has been done by bringing together, under controlled conditions, a large number of varieties of widely diverse origin and degree of adaptation to the local climatic conditions, growing them over a series of years, and making a study of the physical and chemical character of the fruit, with simultaneous study and analysis of the climatic conditions. It was believed that if varieties have only a limited capacity of adjustment to environment, those which found it impossible to adjust themselves to the climatic conditions would manifest the fact by constant departure from their normal composition and character as grown under conditions to which they are adjusted. The variations in seasonal conditions which occur in the

course of a series of years should also make for better development of one or another group according as the particular season simulates that of a warmer or cooler latitude. If the variations in seasonal conditions were sufficiently wide and the experiments were continued long enough to permit checking of the results against themselves, it was believed that it would be possible to obtain a valuation of the climatic factors in terms of the composition of the fruit, without modifications due to differences in soils, cultural treatment, or other factors not controllable in studies of material collected from widely separated sources.

In the course of a systematic study of the effects of seasonal variations in climatic conditions upon the chemical composition of apples (*1*, *2*), approximately 100 of the varieties assigned by Shaw to various optimum temperature groups have been employed. These were growing together in the apple variety collection of the Bureau of Plant Industry, United States Department of Agriculture, at the Arlington Experiment Farm, Rosslyn, Va., near Washington, D. C. For some 70 of these, analyses of the expressed juices of the fruit were regularly made each year for all the varieties bearing crops of normal size, over a period of six years. For about 30 additional varieties analyses were made in two or three years of the period, but not necessarily in consecutive years or in every year in which the trees were in fruit. All of the temperature groups are represented, most of the more important ones by a majority of their members.

The conditions under which the samples were taken have been stated in detail elsewhere (*1*) and will be only briefly summarized here. The trees, two of each variety, were 13 to 16 years of age at the time the first samples of fruit were taken in 1920. They were in all cases free of discoverable disease, making normal growth, and in condition considered typical for healthy trees of the variety. None showed evidence of lack of adjustment to the local conditions. The samples of fruit employed in every case consisted of 1 to 5 bushels of the unsorted tree-run fruit of the mixed crop of the two trees of the variety. The fruit was held in cellar storage or, in a few cases, in cold storage for a short time, followed by transfer to cellar storage until it had attained proper condition for pressing, all the samples being brought to the same degree of ripeness. Pressing was so carried out as to obtain a uniform degree of extraction of the juice, and portions for analysis were taken only after thorough stirring of the bulk sample to insure uniformity. Analyses were always begun as soon as pressing was completed and were always finished on the same day.

ANALYTICAL RESULTS

In the tabulation of the analytical data (Table 1) the varieties have been arranged by optimum temperature groups, beginning with the lowest or 52° F. group and ending with the highest or 67° group.

The average mean temperature at Washington for the seven months, March to September, inclusive, which is the period employed by Shaw in computing mean summer temperature, is 64.5° F. For

the six years during which the analyses were being made, the variation in mean summer temperature was from 3.7 degrees above the 50-year average to 1.6 degrees below it, or a range of 5.3 degrees. For the various years the means were as follows: 1920, 64° F.; 1921, 68.2°; 1922, 65.9°; 1923, 65.4°; 1924, 62.9°; 1925, 66.3°.

On the basis of the conclusions reached by Shaw—namely, that temperature is the dominant factor in determining quality, that every apple variety has an optimum temperature at which it attains its best development, and that when grown at temperatures as much as 2 degrees above or below the optimum it undergoes definite modifications, physical and chemical, which result in lowering of dessert and keeping quality—certain general tendencies should be at once apparent upon examination of the analytical data. Some of these may be stated at this point.

1. Since the mean summer temperature at the Arlington Experiment Farm approximates the optimum for the high-temperature groups, it should follow that the varieties of the 64° to 67° F. groups should attain their best development year after year without marked departures therefrom.

2. Since the members of the 52° to 63° groups are growing at the Arlington farm under summer temperatures higher than their various optima by amounts ranging from 2 to 13 degrees, they should constantly show evidence of injurious effects of the excessive temperatures in the form of modification in composition and keeping quality of the fruit.

3. Such modifications due to excessive temperature should become evident in the 62° group, of which Akin, Grimes Golden, and York Imperial are representatives, and should progressively increase through the groups to a maximum in Baxter, Beitigheimer, Yellow Transparent, and Okabena, of the 53° and 52° groups.

4. The actual summer means during the period show considerable variation from the average, dropping to the 63° level in 1924 and rising above the optimum for the highest temperature group in 1921. The low temperature of 1924 should be productive of retarded maturity and lowered dessert and keeping quality in the 64° to 67° groups, while the quality of the 61° to 63° groups should be improved by reason of the nearer approach to their optimum temperature conditions. In 1921 the excessively high seasonal average of 68.2° F. should result in an acceleration of maturity and decline in quality which should be especially evident in the 63° to 67° groups when the results are compared with those of cooler years. In some degree, at least, the extremes occurring in these two years should be productive of detectable effects opposite in character throughout a considerable number of groups.

5. All the effects just stated should be most marked in the late-maturing long-season varieties and less evident in early-maturing varieties.

TABLE 1.—*Analytical data on apple varieties (arranged by optimum temperature groups)*

Temperature (°F.) group and variety	Date picked	Date analyzed	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar	Acid as malic	Total astringency	Tannin	Non-tannins	Total solids
52 group:										
Okabena	Aug. 14, 1920	Sept. 19	6.40	1.84	8.24	0.988	0.0802	0.0334	0.0468	------
	Aug. 29, 1924	Sept. 2	5.80	2.32	8.12	.477	.0891	.0326	.0565	------
53 group:										
Arctic	Sept. 28, 1922	Dec. 8	8.26	2.15	10.41	.439	.1155	.0358	.0797	------
	Sept. 16, 1923	Nov. 15	9.13	4.84	13.97	.608	.1648	.0622	.1026	16.76
	Sept. 21, 1924	Oct. 2	6.72	3.38	10.10	.525	.1660	.0760	.0900	------
	Sept. 10, 1925	Sept. 26	8.62	1.84	10.46	.360	.1265	.0518	.0747	13.33
Baxter	Sept. 13, 1923	Sept. 27	6.94	3.87	10.81	.634	.1010	.0308	.0702	13.06
	Sept. 13, 1924	Oct. 7	4.80	2.24	7.04	.340	.0780	.0257	.0523	------
	Sept. 17, 1925	Sept. 24	7.02	2.30	9.32	.352	.0932	.0414	.0518	11.81
Bietigheimer	Aug. 11, 1920	Sept. 21	5.90	1.77	7.67	.762	.0985	.0447	.0538	9.48
	Aug. 1, 1922	Aug. 2	7.86	1.30	9.16	.820	.1126	.0166	.0960	10.92
Bismarck	Aug. 12, 1921	Sept. 6	8.16	3.13	11.29	.427	------	------	------	------
	Sept. 8, 1922	Dec. 14	7.86	2.02	9.88	.688	.0826	.0227	.0599	10.57
	Oct. 8, 1924	Oct. 15	8.63	.41	9.04	.630	.1435	.0550	.0885	11.51
Dudley	Aug. 17, 1920	Sept. 2	8.40	1.78	10.18	.752	------	------	------	------
	July 13, 1922	July 28	6.21	3.15	9.36	1.093	.1369	.0245	.1124	11.98
	Aug. 4, 1923	Aug. 13	5.90	2.30	8.20	.762	.1223	.0478	.0745	10.58
	Sept. 5, 1924	Sept. 12	5.08	2.58	7.66	.545	.0791	.0351	.0440	------
Tetofski	June 25, 1922	June 30	5.10	2.38	7.48	.614	.1451	.0511	.0940	8.68
	July 1, 1923	July 6	5.18	3.50	8.68	.721	.1436	.0706	.0730	9.93
Yellow Transparent	June 26, 1922	June 30	6.34	1.56	7.90	.680	.1942	.1125	.0817	9.24
	July 9, 1923	July 18	7.35	2.07	9.42	1.400	.2270	.0876	.1394	12.17
	July 23, 1924	July 30	5.31	.77	6.08	.439	.1360	.0380	.0980	9.60
	July 11, 1925	July 17	5.92	1.61	7.53	.486	.0753	.0255	.0498	------
54 group:										
Fameuse	Sept. 12, 1920	Sept. 27	10.00	1.26	11.26	.420	------	------	------	12.71
	Sept. 27, 1923	Oct. 4	8.98	3.05	12.03	.580	.0960	.0308	.0652	15.45
	Sept. 15, 1924	Sept. 25	7.12	2.32	9.44	.454	.0900	.0362	.0538	------
	Sept. 15, 1925	Sept. 23	8.80	2.48	11.28	.325	.0996	.0454	.0542	13.95
Gideon	Aug. 18, 1920	Sept. 16	8.94	1.08	10.02	.678	------	------	------	------
	Oct. 3, 1922	Oct. 6	7.62	2.55	10.17	.456	.0956	.0477	.0479	12.31
	Sept. 5, 1924	Sept. 19	7.46	1.02	8.48	.362	.1080	.0605	.0475	------
Milwaukee	Aug. 30, 1922	---do----	7.54	1.24	8.78	.654	.0712	.0304	.0408	11.04
	Sept. 24, 1924	Oct. 10	6.26	.94	7.20	.805	.1150	.0395	.0755	------
Red Astrachan	June 26, 1922	June 30	6.82	2.76	9.58	.960	.2095	.0787	.1308	11.63
	July 14, 1923	July 18	7.46	3.21	10.67	1.380	.2550	.1180	.1370	13.48
	Nov. 1, 1920	Nov. 20	8.86	2.02	10.88	.610	------	------	------	12.87
Walbridge	Sept. 13, 1921	Oct. 16	8.64	2.77	11.41	.571	------	------	------	------
	Sept. 26, 1922	Sept. 29	8.10	1.52	9.62	.680	.1034	.0591	.0443	13.14
	Oct. 20, 1923	Oct. 25	10.40	2.96	13.36	.535	.1052	.0452	.0600	15.16
	Sept. 13, 1924	Oct. 9	8.90	1.24	10.14	.660	.1225	.0445	.0780	------
	Sept. 23, 1925	Nov. 3	6.77	1.23	8.00	.412	.0977	.0432	.0545	10.87
Wolf River	Sept. 1, 1920	Oct. 2	7.39	1.38	8.77	.520	------	------	------	------
	Aug. 19, 1922	Aug. 25	5.68	1.96	7.64	.786	.0766	.0235	.0531	10.18
	Sept. 27, 1923	Sept. 29	7.87	1.81	9.68	.740	.0940	.0352	.0588	13.22
	Sept. 15, 1924	Sept. 20	5.76	1.86	7.62	.559	.0765	.0342	.0423	------
	Sept. 16, 1925	Sept. 23	5.70	3.01	8.71	.560	.0750	.0333	.0417	11.17
55 group:										
Blenheim	Sept. 13, 1922	Dec. 12	7.05	4.65	11.70	.646	.0650	.0237	.0413	13.02
	Sept. 13, 1923	Nov. 21	7.10	7.01	14.11	.870	.1455	.0721	.0734	16.00
	Oct. 8, 1924	Oct. 21	6.64	4.58	11.22	.590	.0945	.0423	.0522	------
Cox Orange	Sept. 26, 1922	Nov. 2	7.27	3.82	11.09	.401	.1203	.0539	.0664	------
	Sept. 14, 1923	Sept. 27	7.22	4.78	12.00	.690	.1107	.0397	.0710	13.64
Gravenstein	Aug. 4, 1923	Aug. 13	6.82	1.79	8.61	.605	.1035	.0436	.0599	10.94
	July 27, 1925	Aug. 16	5.73	1.46	7.19	.582	.1326	.0564	.0762	------
Mann	Oct. 13, 1922	Oct. 20	8.58	2.95	11.53	.558	.1088	.0495	.0593	13.71
	Oct. 20, 1923	Oct. 22	8.36	5.26	13.62	.690	.1112	.0477	.0635	16.31
	Nov. 4, 1924	Dec. 1	8.92	1.48	10.40	.580	.1090	.0169	.0921	------
	Sept. 25, 1925	Nov. 16	10.44	2.98	13.42	.417	.1330	.0686	.0644	16.75
McMahon	Aug. 7, 1922	Aug. 8	6.92	.58	7.50	.983	.1349	.0287	.1062	10.07
	Aug. 15, 9123	Aug 17	6.36	1.88	8.24	1.016	.0870	.0378	.0492	9.81
	Aug. 29, 1924	Sept. 3	6.35	1.35	7.70	.752	.0937	.0214	.0723	------
	Aug. 1, 1925	Sept. 8	6.06	2.68	8.74	.508	.0876	.0328	.0548	10.94
Northwestern Greening	Oct. 1, 1920	Nov. 1	8.48	2.21	10.69	.500	------	------	------	13.41
	Sept. 30, 1921	Oct. 24	8.69	2.51	11.20	.678	------	------	------	------
	Oct. 7, 1922	Oct. 12	7.84	2.56	10.40	.368	.0938	.0430	.0508	13.45
	Sept. 28, 1923	Nov. 12	8.36	2.21	10.57	.420	.1174	.0617	.0557	14.28
	Nov. 4, 1924	Nov. 15	8.12	1.09	9.21	.339	.0878	.0278	.0600	------
	Oct. 5, 1925	Nov. 24	9.16	1.75	10.91	.378	.0735	.0177	.0558	12.84
Patten	Aug. 24, 1920	Sept. 17	6.40	.92	7.32	.678	.0513	.0113	.0400	9.64
	Aug. 15, 1922	Aug. 18	7.55	1.47	9.02	.964	.1226	.0347	.0879	------
	Sept. 24, 1924	Oct. 2	5.38	1.58	6.96	.630	.1250	.0578	.0672	------

TABLE 1.—*Analytical data on apple varieties (arranged by optimum temperature groups)*—Continued

Temperature (°F.) group and variety	Date picked	Date analyzed	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar	Acid as malic	Total astringency	Tannin	Non-tannins	Total solids
55 group—Continued.										
Salome	Sept. 23, 1922	Dec. 9	8.80	1.60	10.40	0.654	0.0466	0.0090	0.0376	13.25
	Oct. 20, 1923	Oct. 22	8.41	4.79	13.20	.667	.0831	.0299	.0532	14.08
	Oct. 8, 1924	Oct. 10	7.58	2.98	10.56	.773	.0970	.0190	.0780	------
	Sept. 15, 1925	...do.....	10.06	2.15	12.21	.482	.0927	.0285	.0642	------
Scott Winter	Sept. 23, 1922	Sept. 26	6.73	3.39	10.12	1.030	.0825	.0434	.0391	12.36
	Oct. 4, 1923	Nov. 5	6.56	3.62	10.18	.930	.1029	.0370	.0659	12.16
	Sept. 27, 1924	Oct. 4	10.26	6.30	16.56	.976	.1030	.0403	.0627	18.33
	Sept. 22, 1925	Oct. 16	7.22	2.25	9.47	.712	.1108	.0398	.0710	12.26
56 group:										
Baldwin	Oct. 11, 1920	Nov. 2	8.72	1.39	10.11	.630	------	------	------	12.96
	Sept. 2, 1921	Nov. 6	9.00	3.77	12.77	.595	------	------	------	------
	Oct. 3, 1922	Oct. 5	7.36	3.17	10.53	.571	.0885	.0324	.0561	------
	Oct. 26, 1923	Oct. 31	9.40	5.56	14.96	.635	.1346	.0465	.0881	16.02
	Oct. 20, 1924	Oct. 30	7.24	4.24	11.48	.430	.1237	.0259	.0978	------
	Sept. 16, 1925	Oct. 6	6.76	3.43	10.19	.424	.0953	.0343	.0610	------
Early Harvest	July 9, 1922	July 10	4.60	3.32	7.92	.901	.1676	.0971	.0705	10.39
	July 16, 1923	July 23	4.68	2.16	6.84	.552	.1221	.0528	.0693	------
Golden Russet	Oct. 8, 1920	Oct. 26	10.28	.39	10.67	.478	.0900	.0332	.0568	12.39
	Sept. 23, 1922	Nov. 17	11.01	1.33	12.34	.476	.0860	.0223	.0637	------
	Sept. 28, 1923	Oct. 5	9.43	3.55	12.98	.605	.0961	.0386	.0575	15.46
	Oct. 8, 1924	Oct. 21	9.00	2.82	11.82	.447	.0800	.0303	.0497	------
McIntosh	Sept. 1, 1920	Sept. 16	8.13	1.66	9.79	.423	------	------	------	------
	Sept. 1, 1922	Sept. 5	8.03	1.39	9.42	.566	.0966	.0518	.0448	11.36
	Sept. 5, 1923	Sept. 13	8.00	3.34	11.34	.646	.1248	.0616	.0632	13.44
	Sept. 13, 1924	Sept. 25	7.04	3.36	10.40	.419	.0717	.0294	.0423	------
	Aug. 21, 1925	Sept. 8	6.66	2.75	9.41	.371	.1040	.0398	.0642	11.84
Northern Spy	Sept. 28, 1922	Nov. 3	8.12	2.86	10.98	.393	.1239	.0425	.0814	13.09
	Sept. 29, 1924	Oct. 8	6.54	3.16	9.70	.567	.1055	.0403	.0652	------
	Sept. 16, 1925	Sept. 22	8.06	3.32	11.38	.495	.1340	.0656	.0684	13.61
Ontario	Sept. 21, 1922	Sept. 23	5.72	1.74	7.46	.667	.0738	.0373	.0365	8.66
	Oct. 1, 1924	Oct. 6	5.74	1.28	7.02	.805	.1400	.0757	.0643	------
Sutton	Oct. 15, 1920	Nov. 11	6.72	3.20	9.92	.386	------	------	------	------
	Sept. 23, 1922	Nov. 3	7.36	2.78	10.14	.456	.1071	.0354	.0717	12.71
	Sept. 23, 1923	Oct. 5	7.58	4.92	12.50	.615	.0815	.0267	.0548	13.37
	Sept. 24, 1924	Oct. 8	11.94	1.76	13.70	.585	.0960	.0368	.0592	------
Tolman Sweet	Oct. 1, 1925	Oct. 6	7.18	5.38	12.56	.384	.1170	.0470	.0700	15.52
	Oct. 22, 1923	Nov. 2	7.78	5.63	13.41	.222	.0900	.0387	.0513	14.26
	Oct. 8, 1924	Oct. 16	6.31	4.19	10.50	.170	.0865	.0410	.0455	------
Tompkins King	Sept. 16, 1920	Oct. 16	7.94	2.06	10.00	.537	------	------	------	------
	Sept. 23, 1922	Dec. 11	8.71	1.74	10.45	.542	.0984	.0501	.0483	13.07
	Sept. 28, 1923	Oct. 8	9.48	3.25	12.73	.410	.1123	.0428	.0695	15.93
	Sept. 24, 1924	Oct. 3	7.23	2.75	9.98	.423	.1030	.0342	.0688	------
	Sept. 15, 1925	Oct. 19	7.26	4.07	11.33	.350	.1075	.0407	.0668	13.65
Wealthy	Aug. 11, 1922	Aug. 14	7.20	1.37	8.57	.709	.0848	.0061	.0787	10.37
	Aug. 23, 1923	Sept. 4	7.33	2.87	10.20	.622	.0796	.0203	.0593	11.79
	Aug. 29, 1924	Sept. 3	7.38	1.75	9.13	.665	.1140	.0575	.0565	11.20
Westfield	Sept. 6, 1920	Oct. 17	9.22	2.30	11.52	.482	------	------	------	------
	Oct. 3, 1922	Oct. 7	7.33	3.03	10.36	.456	.1113	.0561	.0552	12.96
	Oct. 26, 1923	Nov. 2	8.00	5.87	13.87	.525	.1157	.0429	.0728	15.42
	Oct. 14, 1924	Oct. 17	7.86	2.34	10.20	.437	.0840	.0230	.0610	------
	Oct. 7, 1925	Oct. 16	7.24	4.94	12.18	.415	.1200	.0390	.0810	14.95
57 group:										
Babbitt	Aug. 29, 1922	Sept. 14	7.04	2.96	10.00	1.182	.1095	.0348	.0747	12.70
	Sept. 27, 1923	Sept. 29	7.44	3.26	10.70	1.130	.0957	.0317	.0640	12.98
	Sept. 13, 1924	Oct. 8	7.64	2.92	10.56	1.112	.1185	.0370	.0815	------
	Sept. 17, 1925	Oct. 7	8.44	2.01	10.45	.910	.1002	.0337	.0665	13.54
Boiken	Sept. 14, 1920	Sept. 27	6.86	2.10	8.96	.830	------	------	------	------
	Sept. 23, 1922	Oct. 19	6.50	3.98	10.48	.811	.0672	.0274	.0398	11.08
	Sept. 19, 1923	Nov. 30	7.04	3.23	10.27	.589	.0762	.0335	.0427	11.96
	Oct. 8, 1924	Oct. 20	7.00	2.43	9.43	.784	.0635	.0301	.0334	------
	Sept. 3, 1920	Sept. 27	9.68	1.52	11.20	.595	------	------	------	------
Hubbardston	Aug. 25, 1921	...do.....	9.02	3.55	12.57	.480	------	------	------	------
	Sept. 18, 1922	Dec. 11	8.22	2.54	10.76	.598	.0949	.0422	.0527	13.47
	Sept. 27, 1923	Oct. 5	7.18	3.76	10.94	.410	.0746	.0241	.0505	12.75
	Oct. 1, 1925	Oct. 20	6.94	2.95	9.89	.168	.0878	.0377	.0501	11.74
Jefferis	Aug. 14, 1920	Sept. 21	8.12	1.09	9.21	.510	------	------	------	11.25
	Aug. 1, 1921	Sept. 5	7.96	2.62	10.58	.607	------	------	------	------
	July 27, 1922	July 31	7.52	1.04	8.56	.808	.1481	.0418	.1063	10.69
	Aug. 23, 1923	Aug. 30	8.15	5.21	13.36	.642	.1165	.0568	.0597	14.87
	Aug. 29, 1924	Sept. 6	7.98	3.30	11.28	.342	.1050	.0735	.0315	------
	Aug. 8, 1925	Aug. 15	8.24	3.53	11.77	.508	.1010	.0497	.0513	------
Lady Sweet	Sept. 8, 1921	Oct. 6	6.54	2.02	8.56	.216	.1196	.0626	.0570	10.89
	Sept. 8, 1923	Nov. 30	7.49	2.82	10.31	.196	.1031	.0431	.0600	12.00

TABLE 1.—*Analytical data on apple varieties (arranged by optimum temperature groups)*—Continued

Temperature (°F.) group and variety	Date picked	Date analyzed	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar	Acid as malic	Total astringency	Tannin	Non-tannins	Total solids
57 group—Continued.										
Melon	Sept. 25, 1920	Oct. 6	8.98	1.45	10.43	0.354	0.1032	0.0237	0.0795	11.91
	Sept. 1, 1922	Sept. 14	7.25	3.23	10.48	.505	.1190	.0547	.0643	14.03
	Oct. 20, 1923	Oct. 26	7.70	1.74	9.44	.277	.0858	.0403	.0455	10.14
	Oct. 1, 1925	Oct. 12	9.14	1.10	10.24	.195	.1246	.0495	.0751	------
Monmouth	Oct. 7, 1920	Oct. 30	7.74	2.02	9.76	.602	------	------	------	11.85
	Sept. 18, 1922	Sept. 23	7.60	1.99	9.59	.543	.0677	.0286	.0391	12.68
	Oct. 20, 1923	Nov. 6	7.74	3.03	10.77	.386	.0857	.0300	.0557	13.24
	Oct. 21, 1924	...do...	7.06	.96	8.02	.413	.0955	.0287	.0668	------
	Oct. 5, 1925	Nov. 16	9.32	1.75	11.07	.300	.0985	.0403	.0582	12.91
Primate	July 20, 1922	July 21	6.22	3.52	9.74	.478	.1287	.0310	.0977	10.94
	July 20, 1923	July 23	7.34	2.58	9.92	.890	.1424	.0887	.0537	11.32
	Aug. 6, 1924	Aug. 11	7.26	.38	7.64	1.385	.0740	.0318	.0422	------
Pumpkin Sweet	Sept. 27, 1923	Oct. 6	8.82	3.82	12.64	.231	.1036	.0489	.0547	14.34
	Sept. 13, 1924	Oct. 4	7.44	2.86	10.30	.150	.1330	.0505	.0825	------
Roxbury Russet	Oct. 4, 1920	Nov. 2	9.13	2.75	11.88	.557	------	------	------	13.03
	Oct. 4, 1923	Nov. 5	6.29	5.98	12.27	.614	.1130	.0471	.0659	16.84
	Oct. 8, 1924	Oct. 22	6.16	3.94	10.10	.532	.0945	.0373	.0572	------
	Oct. 1, 1925	Oct. 14	8.60	4.60	13.20	.502	.1200	.0365	.0835	16.41
Williams	July 25, 1923	July 30	6.67	4.10	10.77	.551	.1420	.0695	.0725	12.32
	July 29, 1924	Aug. 6	6.67	2.15	8.82	.296	.1275	.0606	.0669	------
	July 21, 1925	July 25	6.71	1.53	8.24	.387	.0856	.0311	.0545	------
58 group:										
Early Joe	July 20, 1922	July 21	6.41	2.19	8.60	.424	.1390	.0583	.0807	9.72
	Aug. 10, 1924	Aug. 11	7.44	.72	8.16	.352	.1742	.0792	.0950	------
Early Strawberry	July 21, 1921	Aug. 3	5.60	2.30	7.90	.644	------	------	------	10.20
	July 25, 1923	July 30	6.18	3.18	9.36	.733	.1375	.0735	.0640	11.20
Ewalt	Aug. 29, 1922	Sept. 16	4.85	2.72	7.57	.595	.1086	.0565	.0521	10.03
	Sept. 10, 1924	Sept. 26	5.79	1.83	7.62	.707	.1250	.0586	.0664	------
Golden Sweet	July 31, 1920	Aug. 6	8.86	1.12	9.98	.144	.1280	.0460	.0820	11.40
	July 25, 1922	July 26	8.37	1.20	9.57	.276	.1768	.0521	.1247	------
	Aug. 2, 1923	Aug. 6	6.09	3.43	9.52	.200	.1880	.0845	.1035	10.72
Lowell	Aug. 14, 1920	Aug. 21	6.34	3.14	9.48	.570	.1260	.0670	.0590	------
	Aug. 16, 1923	Aug. 24	6.60	3.08	9.68	.510	.1370	.0710	.0660	11.07
Mother	Sept. 1, 1920	Sept. 19	9.46	.57	10.03	.413	------	------	------	------
	Aug. 30, 1922	Sept. 15	6.89	4.15	11.04	.347	.1034	.0313	.0721	13.21
	Sept. 8, 1923	Sept. 22	6.86	4.48	11.34	.422	.1095	.0420	.0675	12.50
	Aug. 29, 1924	Sept. 15	6.97	4.37	11.34	.487	.1215	.0717	.0498	------
	Sept. 14, 1925	Sept. 22	8.24	4.02	12.26	.267	.1242	.0742	.0500	14.08
Red June	July 15, 1922	July 17	6.01	1.84	7.85	.551	.1584	.0603	.0981	10.56
	July 20, 1923	July 23	6.06	2.93	8.99	.686	.1373	.0713	.0660	10.30
	July 28, 1924	Aug. 13	6.54	2.43	8.97	.350	.1180	.0390	.0790	------
Swaar	Oct. 8, 1920	Oct. 30	10.13	3.77	13.90	.612	------	------	------	14.66
	Sept. 23, 1922	Oct. 31	8.07	3.71	11.78	.598	.1115	.0398	.0717	14.97
	Sept. 28, 1923	Oct. 8	8.14	4.64	12.78	.587	.0832	.0276	.0556	15.12
	Oct. 11, 1924	Oct. 22	9.03	3.64	12.67	.762	.1280	.0525	.0755	------
	Oct. 1, 1925	Oct. 23	8.06	4.42	12.48	.437	.0705	.0135	.0570	14.92
Twenty Ounce	Sept. 16, 1923	Nov. 28	8.28	3.57	11.85	.572	.0839	.0394	.0445	14.76
	Sept. 13, 1924	Sept. 18	6.15	2.95	9.10	.576	.0833	.0368	.0465	------
Winter Banana	Aug. 22, 1921	Sept. 19	7.40	3.45	10.85	.293	------	------	------	------
	Sept. 6, 1922	Sept. 13	6.63	4.10	10.73	.317	.1181	.0634	.0547	12.42
	Sept. 5, 1923	...do...	8.20	2.33	10.53	.371	.1530	.0540	.0990	12.02
	Sept. 18, 1925	Oct. 5	9.16	1.68	10.84	.182	.1390	.0570	.0820	13.18
59 group:										
Benoni	July 19, 1922	Aug. 9	6.04	2.80	8.84	.426	.1308	.0429	.0879	9.62
	July 30, 1923	July 30	6.04	4.30	10.34	.655	.1485	.0700	.0785	11.62
Delicious	Sept. 25, 1920	Oct. 6	9.55	1.05	10.60	.254	------	------	------	------
	Sept. 21, 1921	Oct. 18	7.39	4.30	11.69	.313	------	------	------	------
	Oct. 7, 1922	Oct. 11	7.28	2.82	10.10	.279	.0868	.0377	.0491	12.46
	Oct. 14, 1924	Nov. 4	8.24	1.98	10.22	.216	.0760	.0322	.0438	------
Esopus Spitzenburg	Sept. 23, 1922	Nov. 16	8.41	2.23	10.64	.451	.0700	.0205	.0495	14.13
	Oct. 4, 1924	Oct. 15	7.86	4.68	12.54	.778	.0918	.0300	.0618	------
Haas	Aug. 19, 1922	Aug. 21	8.71	2.67	11.38	1.053	.1191	.0255	.0936	13.26
	Sept. 16, 1923	Dec. 6	7.26	2.15	9.41	.445	.0852	.0272	.0580	14.30
	Sept. 5, 1924	Sept. 19	7.05	1.57	8.62	.583	.1170	.0410	.0760	------
Jonathan	Sept. 14, 1925	Sept. 22	7.72	3.11	10.83	.477	.1320	.0500	.0820	13.84
	Oct. 21, 1922	Nov. 3	8.32	2.77	11.09	.380	.0938	.0336	.0602	13.02
	Oct. 16, 1923	Nov. 27	7.20	5.68	12.88	.542	.1077	.0431	.0646	15.34
King David	Aug. 30, 1921	Nov. 1	7.79	2.91	10.70	.372	------	------	------	------
	Sept. 23, 1922	Nov. 17	7.79	4.52	12.31	.561	.0749	.0263	.0486	15.56
	Sept. 19, 1923	Nov. 16	9.28	4.42	13.70	.651	.0692	.0092	.0600	14.48
Kinnard	Sept. 6, 1921	Oct. 8	6.34	4.44	10.78	.481	.0893	.0253	.0640	------
	Sept. 28, 1923	Nov. 5	7.82	3.94	11.76	.435	.1080	.0439	.0641	13.66
	Oct. 8, 1924	Oct. 22	6.64	3.38	10.02	.470	.1045	.0473	.0572	------
	Oct. 15, 1925	Oct. 31	7.54	2.09	9.63	.314	.0899	.0302	.0597	12.19

TABLE 1.—*Analytical data on apple varieties (arranged by optimum temperature groups)*—Continued

Temperature (°F.) group and variety	Date picked	Date analyzed	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar	Acid as malic	Total astringency	Tannin	Non-tannins	Total solids
59 group—Continued.										
Red Canada	Oct. 1, 1920	Oct. 6	7.86	2.57	10.43	0.316	0.0700	0.0210	0.0490	12.09
	Sept. 27, 1923	do	9.59	3.97	13.56	.422	.0832	.0430	.0402	15.57
Wagener	Sept. 16, 1923	Dec. 4	6.24	3.88	10.12	.567	.0795	.0290	.0505	13.12
	Oct. 1, 1924	Oct. 7	6.06	3.48	9.54	.570	.0917	.0232	.0685	------
60 group:										
Domine	Oct. 7, 1922	Oct. 11	6.78	3.15	9.93	.426	.0947	.0711	.0236	12.83
	Oct. 8, 1923	Nov. 19	8.55	4.43	12.98	.514	.1110	.0606	.0504	12.10
	Oct. 11, 1924	Oct. 21	7.13	2.71	9.84	.443	.0635	.0267	.0368	------
	Sept. 17, 1925	Oct. 8	8.70	3.19	11.89	.372	.0920	.0378	.0542	14.84
	Sept. 18, 1920	Oct. 20	9.63	1.14	10.77	.374	------	------	------	12.16
Fallawater	Sept. 18, 1922	Oct. 31	9.26	------	9.26	.221	.1124	.0355	.0769	12.23
	Sept. 27, 1923	Oct. 4	8.61	3.42	12.03	.418	.0780	.0162	.0618	15.42
	Oct. 8, 1924	Oct. 11	7.53	2.24	9.77	.256	.0832	.0316	.0516	------
	July 26, 1922	July 28	6.23	1.26	7.49	1.104	.1359	.0123	.1236	9.86
Hagloe Crab	Sept. 3, 1923	Sept. 11	6.49	1.81	8.30	.484	.0930	.0430	.0500	8.86
	Sept. 5, 1924	Sept. 12	6.24	.84	7.08	.494	.1025	.0495	.0530	------
	Aug. 21, 1925	Sept. 3	5.58	2.08	7.66	.449	.0965	.0425	.0540	10.94
	Oct. 8, 1921	Oct. 26	7.86	3.05	10.91	.620	------	------	------	------
	Oct. 3, 1922	Oct. 11	7.49	2.60	10.09	.507	.1078	.0499	.0579	13.01
McAfee	Oct. 13, 1923	Oct. 26	9.34	2.66	12.00	.394	.1035	.0428	.0607	13.60
	Oct. 21, 1924	Nov. 13	8.24	1.34	9.58	.375	.1132	.0422	.0710	------
	Oct. 15, 1925	Nov. 16	8.56	1.68	10.24	.235	.1210	.0480	.0730	11.95
	Oct. 3, 1922	Oct. 5	7.22	2.96	10.18	.510	.0771	.0228	.0543	------
Newtown Spitzenburg	Oct. 4, 1923	Nov. 19	7.44	3.87	11.31	.367	.0852	.0442	.0410	14.02
	Oct. 18, 1924	Nov. 25	6.31	1.61	7.92	.325	.0702	.0314	.0388	------
	Sept. 25, 1925	Oct. 17	7.02	2.98	10.00	.273	.0760	.0302	.0458	11.88
	Sept. 2, 1920	Sept. 23	8.90	2.01	10.91	.388	.0920	.0352	.0568	12.88
Rambo	Oct. 20, 1923	Oct. 26	9.48	4.06	13.54	.402	.1002	.0445	.0557	14.84
	Sept. 14, 1924	Sept. 19	6.76	1.70	8.46	.398	.0795	.0070	.0725	------
	Oct. 7, 1922	Oct. 9	6.62	3.79	10.41	.360	.0877	.0264	.0613	11.99
Rome Beauty	Oct. 9, 1923	Oct. 18	6.88	5.23	12.11	.392	.0720	.0164	.0556	13.41
	Nov. 4, 1924	Nov. 29	6.20	2.02	8.22	.264	.0636	.0146	.0690	11.62
	Sept. 23, 1925	Nov. 3	5.99	2.73	8.72	.273	.0993	.0329	.0664	11.28
	Sept. 3, 1921	Sept. 26	9.07	3.81	12.88	.672	------	------	------	------
	Sept. 28, 1922	Oct. 13	6.77	4.12	10.89	.553	.0747	.0204	.0543	12.09
Smokehouse	Oct. 4, 1923	Nov. 14	9.02	4.06	13.08	.559	.1200	.0472	.0728	15.70
	Sept. 13, 1924	Oct. 8	7.00	1.80	8.80	.440	.1020	.0412	.0608	11.20
	Oct. 3, 1925	Oct. 22	9.60	2.35	11.95	.378	.1225	.0457	.0768	15.12
Yellow Newtown	Oct. 3, 1922	Oct. 18	6.84	4.03	10.87	.537	.0926	.0403	.0523	13.92
	Oct. 11, 1924	Oct. 21	7.13	3.19	10.32	.593	.0747	.0260	.0487	14.12
61 group:										
Lankford	Sept. 2, 1921	Sept. 13	7.06	4.59	11.65	.504	.0873	.0401	.0472	------
	Oct. 11, 1924	Oct. 20	6.83	3.52	10.35	.507	.0925	.0428	.0497	------
Ortley	Sept. 23, 1922	Sept. 23	6.04	3.23	9.27	.522	.0634	.0348	.0286	11.42
	Sept. 27, 1923	Sept. 29	8.00	3.24	11.24	.732	.0842	.0342	.0500	13.24
	Oct. 8, 1924	Oct. 21	7.64	2.29	9.93	.400	.0713	.0318	.0395	------
Smith Cider	Sept. 23, 1922	Dec. 11	7.74	2.11	9.85	.524	.0879	.0264	.0615	12.89
	Oct. 15, 1924	Oct. 17	6.68	3.45	10.13	.438	.0925	.0317	.0608	13.24
	Oct. 9, 1920	Oct. 20	8.68	1.01	9.69	.630	------	------	------	11.12
	Sept. 11, 1921	Oct. 13	8.40	3.08	11.48	.651	------	------	------	------
White Pippin	Oct. 13, 1922	Oct. 19	6.34	4.70	11.04	.522	.0717	.0275	.0442	------
	Sept. 28, 1923	Nov. 14	6.62	4.77	11.39	.470	.0995	.0430	.0565	13.42
	Oct. 4, 1924	Oct. 9	6.04	4.02	10.06	.595	.0950	.0308	.0642	------
	Oct. 13, 1920	Nov. 2	7.86	2.16	10.02	.636	------	------	------	13.82
	Sept. 2, 1921	Nov. 6	9.00	3.77	12.77	.595	------	------	------	------
Yellow Bellflower	Oct. 3, 1922	Oct. 5	7.36	3.17	10.53	.571	.0885	.0324	.0561	------
	Oct. 26, 1923	Oct. 31	9.40	5.56	14.96	.635	.1346	.0465	.0881	16.02
	Sept. 16, 1925	Oct. 6	6.76	3.43	10.19	.424	.0953	.0343	.0610	------
62 group:										
	Sept. 11, 1921	Oct. 6	8.64	3.31	11.95	.465	------	------	------	------
	Oct. 27, 1922	Dec. 5	8.43	2.03	10.46	.432	.1099	.0613	.0486	14.28
Akin	Oct. 20, 1923	Oct. 25	9.46	3.20	12.66	.391	.0951	.0557	.0394	14.58
	Oct. 8, 1924	Oct. 17	7.68	1.82	9.50	.384	.0815	.0310	.0505	------
	Oct. 15, 1925	Oct. 31	8.48	2.80	11.28	.314	.0772	.0212	.0560	13.56
	Sept. 18, 1922	Nov. 14	8.44	5.16	13.60	.380	.0911	.0283	.0628	15.02
Grimes Golden	Oct. 14, 1924	Oct. 16	6.34	4.53	10.87	.440	.0797	.0307	.0490	------
	Oct. 13, 1922	Nov. 3	6.57	4.13	10.70	.279	.0982	.0292	.0690	11.84
	Sept. 28, 1923	Oct. 8	7.18	5.14	12.32	.476	.0763	.0216	.0547	13.97
Huntsman	Oct. 8, 1924	Oct. 15	6.98	3.90	10.88	.502	.0832	.0154	.0678	------
	Oct. 1, 1925	Oct. 26	6.66	2.48	9.14	.260	.0859	.0309	.0550	11.16
	Sept. 13, 1921	Sept. 26	8.20	3.16	11.36	.442	------	------	------	------
	Sept. 23, 1922	Nov. 15	7.46	3.30	10.76	.412	.1208	.0551	.0657	13.46
Ingram	Oct. 8, 1923	Oct. 12	8.00	2.77	10.77	.443	.0727	.0265	.0462	12.49
	Oct. 7, 1925	Nov. 23	7.92	3.36	11.28	.332	.1205	.0495	.0710	13.31

TABLE 1.—*Analytical data on apple varieties (arranged by optimum temperature groups)*—Continued

Temperature (°F.) group and variety	Date picked	Date analyzed	Constituents (per cent)							
			Reducing sugar	Sucrose as invert sugar	Total sugar	Acid as malic	Total astringency	Tannin	Non-tannins	Total solids
62 group—Continued.										
Ralls	Sept. 2, 1921	Oct. 15	7.39	4.98	12.37	0.680				
	Oct. 7, 1922	Oct. 12	7.81	3.07	10.88	.583	0.0789	0.0246	0.0543	14.92
	Oct. 20, 1923	Oct. 26	8.32	3.37	11.69	.420	.0727	.0282	.0445	13.13
	Oct. 14, 1924	Oct. 23	7.62	2.89	10.51	.355	.0640	.0211	.0429	
Stark	Oct. 10, 1925	Nov. 18	8.76	2.52	11.28	.286	.0950	.0368	.0582	13.31
	Oct. 15, 1922	Oct. 18	7.39	3.30	10.69	.416	.0649	.0412	.0237	12.67
	Oct. 26, 1923	Nov. 2	8.97	4.89	13.86	.481	.0984	.0368	.0616	15.58
	Oct. 21, 1924	Dec. 1	7.72	1.64	9.36	.291	.0885	.0345	.0540	11.29
York Imperial	Sept. 13, 1921	Oct. 16	9.00	2.04	11.04	.588				
	Sept. 25, 1922	Oct. 12	10.71	1.58	12.29	.491	.0657	.0050	.0607	13.49
	Nov. 1, 1923	Nov. 2	8.36	4.12	12.48	.467	.0770	.0315	.0455	14.80
	Oct. 14, 1924	Oct. 17	7.13	2.43	9.56	.463	.0516	.0136	.0380	
63 group:										
Arkansas Black	Oct. 12, 1920	Nov. 3	7.42	3.16	10.58	.513				
	Sept. 23, 1921	Oct. 16	8.21	3.27	11.48	.625				
	Sept. 23, 1922	Dec. 1	8.50	1.84	10.34	.536	.0747	.0273	.0474	12.97
	Sept. 28, 1923	Dec. 3	7.18	2.56	9.74	.439	.0930	.0374	.0556	13.92
	Oct. 7, 1925	Nov. 24	9.02	2.44	11.46	.360	.0925	.0325	.0600	12.82
Stayman Winesap	Sept. 10, 1921	Oct. 10	8.16	3.17	11.33	.498	.1165	.0540	.0625	
	Oct. 11, 1922	Oct. 21	6.72	3.78	10.50	.507	.0947	.0443	.0504	13.90
64 group:										
Ben Davis	Oct. 16, 1922	Oct. 30	7.83	2.16	9.99	.385	.1010	.0380	.0630	
	Nov. 4, 1924	Dec. 1	7.68	2.38	10.06	.350	.0945	.0329	.0616	
Gano	Sept. 10, 1921	Oct. 11	6.25	2.93	9.18	.510				
	Oct. 3, 1922	Oct. 10	7.44	2.64	10.08	.406	.1043	.0324	.0719	11.73
	Sept. 28, 1923	Dec. 3	7.38	3.53	10.91	.321	.1094	.0500	.0594	11.62
Lawver	Oct. 12, 1920	Oct. 30	6.26	1.46	7.72	.617				
	Sept. 2, 1921	Oct. 21	8.20	3.43	11.63	.565				
	Sept. 29, 1922	Dec. 13	7.77	2.37	10.14	.563	.0729	.0342	.0387	
	Sept. 27, 1923	Sept. 29	7.43	3.77	11.20	.694	.0940	.0248	.0692	12.15
	Sept. 15, 1924	Oct. 9	7.74	2.32	10.06	.500	.1260	.0582	.0678	
Missouri Pippin	Oct. 18, 1920	Nov. 13	9.98	2.00	11.98	.510	.0884	.0177	.0707	13.19
	Sept. 10, 1921	Nov. 17	9.30	2.97	12.27	.706	.1055	.0101	.0954	
	Nov. 4, 1924	Nov. 25	6.97	4.93	11.90	.584	.0947	.0329	.0618	
Oliver Red	Oct. 13, 1922	Dec. 7	7.51	1.59	9.10	.378	.0629	.0342	.0287	12.01
	Oct. 19, 1923	Nov. 30	8.40	5.63	14.03	.294	.0852	.0221	.0631	14.58
Paragon	Oct. 1, 1924	Oct. 4	6.46	3.48	9.94	.482	.1125	.0560	.0565	
	Sept. 2, 1921	Oct. 3	9.02	2.64	11.66	.507				13.71
	Oct. 26, 1923	Nov. 5	8.10	3.79	11.89	.384	.1260	.0480	.0780	
	Nov. 4, 1924	Nov. 22	6.00	2.26	8.26	.332	.0955	.0355	.0600	
Winesap	Nov. 6, 1925	Nov. 25	10.58	2.30	12.88	.308	.1205	.0601	.0604	13.47
	Oct. 7, 1922	Oct. 10	8.40	4.61	13.01	.520	.0850	.0421	.0429	15.07
	Oct. 19, 1924	Oct. 30	7.26	2.99	10.25	.630	.0962	.0480	.0482	14.00
65 group:										
Beach	Oct. 26, 1923	Oct. 31	8.16	4.14	12.30	.398	.0649	.0209	.0440	
	Nov. 4, 1924	Nov. 11	7.54	3.60	11.14	.362	.0726	.0152	.0574	
Collins	Oct. 15, 1920	Oct. 28	9.50	2.50	12.00	.650				13.51
	Sept. 2, 1921	Sept. 19	8.64	2.43	11.07	.802				
	Sept. 30, 1922	Nov. 1	7.52	1.54	9.06	.680	.0872	.0265	.0607	11.46
	Oct. 26, 1923	Oct. 31	7.35	5.15	12.50	.740	.1112	.0222	.0890	
	Oct. 28, 1924	Nov. 4	6.08	3.34	9.42	.517	.0995	.0295	.0700	
	Oct. 7, 1925	Nov. 23	7.82	2.56	10.38	.372	.1058	.0373	.0685	11.57
66 group:										
Buckingham	Sept. 23, 1922	Dec. 9	7.65	2.05	9.70	.431	.0448	.0343	.0105	12.19
	Sept. 27, 1923	Oct. 8	6.26	3.39	9.65	.456	.0994	.0463	.0531	11.67
	Oct. 14, 1924	Oct. 17	6.00	1.42	7.42	.356	.0780	.0335	.0445	
67 group:										
Terry	Sept. 2, 1921	Sept. 24	8.16	2.75	10.91	.662				
	Oct. 22, 1922	Oct. 24	5.98	4.55	10.53	.786	.1133	.0275	.0858	13.66
	Oct. 26, 1923	Oct. 31	5.90	6.24	12.14	.746	.1232	.0460	.0772	16.40
	Nov. 4, 1924	Nov. 15	5.72	6.39	12.11	.667	.1217	.0422	.0795	

The degree to which the behavior of the fruit accords with these expectations based upon Shaw's conclusions is now to be determined by examination of the analytical results. Since the data were collected in the course of a rather comprehensive study of the effect of climatic conditions upon the chemical composition of the fruit, some of the facts established by that study may be briefly summa-

rized, reference being made to the original publication (*1*) for detailed discussion.

In the study to which reference has been made it was found that the chemical composition of a large number of varieties showed definite response to the climatic conditions, more specifically to the amount of sunshine and heat received during the seven growing months. This correlation was of such a nature that the total sugar content of the crop as a whole was highest in that year which received the largest number of hours of sunshine in the growing season (1923), next highest in the year of maximum temperatures and next-to-maximum hours of sunshine (1921), and lowest in the year of subnormal temperatures and normal hours of sunshine (1924). The other years of the period 1920–1925 had intermediate positions corresponding to the degree of heat and amount of sunshine received. In other words, the sugar content of the crop of more than 200 varieties increases en masse with increase in the amount of sunshine and temperature over that normally received at Washington and decreases with decrease in the amounts of these factors below the normal. It was further found that there is a definite correlation between total sugar, sucrose, and acidity such that all three are at a maximum or minimum together. Further, there is a correlation between total sugar and astringent substances such that high total sugars are associated with minimum relative astringency, low total sugars with maximum relative astringency. A very large number of varieties of diverse origin were found to behave as one in these respects.

The results as to ranking of the crop of all the varieties for each of the years concerned with respect to total sugar, acidity, and relative astringency are shown in Table 2, together with the mean temperature and amount of sunshine for the season. The latter is expressed as percentage of the normal hours of sunshine for the season.

TABLE 2.—*Comparative summary of analytical results on apple varieties, 1920–1925*

Year	Mean summer temperature (° F.)	Sunshine (percentage of normal)	Composition of crop, ranked in order of amount of each constituent [a]		
			Total sugar	Acid	Relative astringency
1920	64.0	101.7	5	4	[b]
1921	68.2	105.5	2	1	[b]
1922	65.9	97.9	4	3	2
1923	65.4	108.7	1	2	4
1924	62.9	102.1	6	5	1
1925	66.3	105.0	3	6	3

[a] Rank of 1 indicates largest number of varieties having maximum content of constituent named, 2 next largest, and so on.

[b] Data on astringency not obtained in 1920 and 1921.

It is not to be inferred from what has just been said that every variety without exception behaved in the manner indicated. There were exceptions, but the general result was so clear cut as to compel the conclusion that the behavior of the group of varieties was a physiological response to the climatic environmental factors. Some 70

of the apples here discussed were included in the group of varieties employed. In a broad general way, they responded to the varying climatic conditions in the same manner as did the other members of the group. It would be expected on the basis of Shaw's theory that groups whose optimum temperatures are very close to the mean temperature would respond to greater amounts of sunshine by increased storage of the products of photosynthetic activity in the fruit. Such a result would scarcely be expected, on the basis of Shaw's theory, in groups having optimum temperatures far below those occurring at Washington. A detailed comparative examination of the analytical results for each of the temperature groups in the various years is necessary in order to determine whether the behavior of high and low temperature groups under a given set of conditions is similar or widely divergent.

Such a comparison presents difficulties, for the reason that all the varieties concerned were not analyzed in every year. Thirty of them were analyzed in 2 years only, 19 in 3 years, 27 in 4 years, 18 in 5 years, 4 in 6 years. Data upon astringency were not obtained in 1920 and 1921 except in a few cases. The results of a comparison consequently can not be as conclusive as they would be if the data for every variety were complete, but any pronounced tendencies will be apparent.

RELATION OF CHEMICAL COMPOSITION TO DESSERT QUALITY

Shaw has made in his second paper (*11*) practically the only attempt to be found in the literature to define the relation of "quality" in apples to their chemical composition. To summarize his statement, the apple of high dessert quality is low in insoluble and high in soluble solids, high in total sugars and acid, with a definite ratio between their amounts and with sucrose making up approximately one-third the total sugar content. Good keeping quality is associated with a high content of soluble solids and with a relatively high proportion of the sugar present in the form of sucrose. This statement probably presents as satisfactory a definition of quality in terms of chemical composition as it is possible to make and has been generally accepted as correct. It has been pointed out elsewhere (*1*) that the inclusion of data upon the tannin content of the fruit and the presentation of the figures for acidity, astringency, and sugar in the form of a ratio is a material aid in formulating a conception of the character of the fruit.[3]

It follows from Shaw's definition of quality that within a given variety the specimens having the higher content of soluble solids, total sugars, sucrose, and acid are of better dessert and storage quality than are those of a lower content of all these constituents, and that it is justifiable to rank a group of samples of a given variety as best, second best, and so on down to poorest on the basis of decreasing content of these constituents. This method of reasoning

[3] Chandler (*5*) is inclined to minimize the importance of the sugar-acid ratio as a factor in determining quality in apples, pointing out that the sugar-acid ratio in Green Newtown is approximately the same as in Ben Davis and that Rome Beauty, Fameuse, McIntosh, Jonathan, and Northern Spy have about the same ratio despite their differences in quality. His criticism appears to be based on a misunderstanding of the purpose and function of the sugar-acid ratio, which is an index of quality within the variety rather than between varieties. That Yellow Newtown and Ben Davis have like sugar-acid ratios tells nothing as to their comparative quality; but if several lots of either variety are compared among themselves, they will be found to rank in quality very nearly in accordance with the results of determinations of the sugar-acid ratio, going over to insipid or tart as the balance between the two rises or falls.

was followed by Shaw in comparing the analytical data on samples of the same variety from various localities. It would appear to be legitimate to apply the same process to the product of the same trees over successive years. This has been done in the present instance, and in the subsequent discussion a given variety is considered as having highest dessert quality in that year in which its total sugar, sucrose, and acid were highest, and as ranking progressively lower in quality with decrease in amount of these constituents.

CHARACTER OF THE 1923 CROP

Since 1923 was found to be the year of maximum total sugar, next to maximum acidity, and minimum relative astringency (ratio of total astringent substances to total sugar) in the study to which reference has been made, examination of the data of Table 1 may begin with a determination of the extent to which the same condition is found in the various temperature groups.

TABLE 3.—*Number of varieties in the various temperature groups having maximum and next to maximum total sugar; maximum and next to maximum sucrose; maximum and next to maximum acid content; minimum and next to minimum relative astringency in 1923*

Group (°F.)	Number analyzed in 1923 and in one or more other years	Number showing in 1923—							
		Maximum total sugar	Next to maximum total sugar *	Maximum sucrose	Next to maximum sucrose *	Maximum acid	Next to maximum acid *	Minimum relative astringency	Next to minimum relative astringency *
52	None.	0	0	0	0	0	0	0	0
53	5	4	0	4	0	4	1	2	1
54	4	4	0	3	0	2	0	3	1
55	8	5	2	5	2	5	1	3	2
56	9	7	0	5	3	6	0	4	2
57	11	6	3	8	2	3	2	5	2
58	8	4	2	6	0	3	1	2	1
59	7	6	0	4	1	4	0	6	1
60	8	8	0	5	2	4	1	6	1
61	3	2	1	3	0	1	1	0	0
62	6	4	2	3	2	2	2	3	2
63	1	0	0	0	0	0	0	0	0
64	4	2	2	4	0	1	1	2	0
65	2	2	0	2	0	1	1	2	0
66	1	0	0	1	0	1	0	0	0
67	1	1	0	0	1	0	1	1	0
Total	78	55	12	53	13	37	12	39	13

* Only those varieties which were analyzed in four or five years are included in tabulating next to maximum and next to minimum values.

Table 3 brings together the results of an examination of the analyses made in 1923 in all the groups for the occurrence of maximum total sugars, sucrose, acidity, and minimum relative astringency. Of the 78 varieties analyzed in that year, 55 had maximum total sugar, 53 maximum sucrose, 37 maximum acidity, and 39 minimum relative astringency. In the case of each of these constituents there is also a number of varieties which had next to maximum amounts in 1923; in those varieties which were analyzed in four or five years 12 had next to maximum acidity, 13 had next to minimum astringency, 12 had next to maximum total sugars, and 13 had next to maximum

sucrose. Consideration of maxima alone shows clearly that there was a very pronounced tendency toward attainment of high total sugar and sucrose content in 1923. What is of immediate interest in the present connection is the fact, apparent from the tabulation, that high sugars and high acid content, with accompaying low astringency, are fully as frequent in the low-temperature groups as in those having optimum temperatures close to the mean for the year. In other words, the low-temperature groups utilize an exceptional increase in amount of seasonal sunshine, when grown at materially higher temperatures, just as do the groups for which the temperature is at or near the optimum.

CHARACTER OF THE 1921 CROP

In the study of the large group, 1921 ranked next after 1923 in the amount of total sugar and sucrose present in the crop as a whole, while the acidity was higher than in any other year of the period. Since 1921 was the hottest year of the period, with a mean temperature of 68.2° F., it would be expected, if the optimum-temperature theory holds, that the large excess of heat received by the groups having low optimum temperatures would unfavorably affect their total sugar, sucrose, and acid content. The data are summarized in Table 4.

TABLE 4.—*Number of varieties in the various temperature groups having maximum total sugar, sucrose, and acid content in 1921 (data on astringency not obtained)*

Group (°F.)	Number analyzed in 1921 and in 1 or more other years	Number showing in 1921—		
		Maximum total sugar	Maximum sucrose	Maximum acid
52	None.	0	0	0
53	1	1	1	0
54	1	[a]0	[a]0	0
55	1	1	0	1
56	1	[a]0	[a]0	0
57	3	[b]1	[b]0	1
58	2	1	0	0
59	3	[b]1	2	2
60	2	[c]0	1	2
61	3	[b]2	[b]1	1
62	4	[b]2	2	[b]3
63	2	2	1	1
64	4	2	[a]2	3
65	1	0	0	1
66	None.	0	0	0
67	1	0	0	0
Total	29	[d]13	[e]10	[b]15

[a] Exceeded in amount only by 1923.
[b] 1 other had a higher amount only in 1923.
[c] 3 others had higher amounts only in 1923.
[d] 8 others had maximum in 1923 with next to maximum in 1921.
[e] 7 others had maximum in 1923 and next to maximum in 1921.

The numbers in the various groups examined in 1921 are not large, only a single variety in some of the low and a few of the high-temperature groups. Of a total of 29 analyzed, 13 had their maximum sugar content while 8 others had next to maximum, having had their maxima in 1923. Ten had maximum sucrose, six others next to maximum, with maxima occurring in 1923. Fifteen had maximum acidity and one next to maximum. In all the groups there is a very apparent occurrence of maximum total sugars and sucrose in this

year with next to maximum amounts in those varieties which had their maxima in 1923. Considering the results for the analyses of 1923 and 1921 together, it is clear that nearly all the varieties analyzed in the two years had their maximum sugar content in one or the other of the two rather than indiscriminately over the other years. It is also clear that the high temperature of 1921 (68.2° F.) did not operate to prevent attainment of high total sugar and sucrose content on the part of many members of the low-temperature groups.

CHARACTER OF THE 1924 CROP

The year 1924 was the year of minimum mean summer temperature, 62.9° F., for the period covered by the climatic study. It was the year in which the crop of the varieties analyzed in that study, collectively considered, had minimum total sugar content, next to minimum sucrose and acid content, and maximum astringency. The high acidity which is characteristic of immature fruit was notably absent; instead, acidity was low in practically all varieties. The decline in mean temperature below the normal for the season should bring the groups having low to medium optimum temperatures into better adjustment with the locality and should have the opposite effect upon the high-temperature groups, if the optimum temperature theory holds. Table 5 indicates for the various temperature groups the extent to which their composition in 1924 followed that of the collective group. Of the 75 varieties analyzed in that year, 46 had minimum total sugar, 37 had minimum and 12 next to minimum sucrose, 26 minimum and 16 next to minimum acidity, and 45 maximum and 10 next to maximum astringency. Next to maximum and next to minimum values have been considered only in the case of varieties in which four years' analyses were made.

TABLE 5.—*Number of varieties in the various temperature groups having minimum total sugar, minimum or next to minimum sucrose, minimum or next to minimum acid content, and maximum or next to maximum relative astringency in 1924* [a]

Group (°F.)	Number analyzed in 1924 and in one or more other years	Number showing in 1924—			
		Minimum total sugar	Minimum or next to minimum sucrose	Minimum or next to minimum acid	Maximum or next to maximum relative astringency
52	1	1	0	1	1
53	5	5	3	3	3
54	5	4	4	2	5
55	7	4	4	4	5
56	9	5	4	4	4
57	8	4	5	6	6
58	6	2	4	2	5
59	5	2	4	1	4
60	9	8	8	5	7
61	4	1	2	2	3
62	6	5	5	4	4
63	None.	0	0	0	0
64	6	3	4	4	5
65	2	1	1	2	2
66	1	1	1	1	1
67	1	0	0	1	0
Total	75	46	49	42	55

[a] Next to minimum and next to maximum values in 1924 have been included only in cases in which data for four or five years were available for comparison.

There is consequently a tendency on the part of the whole group toward low sugar and acid content with high astringency, which is about as pronounced as the tendency toward the opposite condition in 1923. When the individual groups are examined, there are no pronounced differences between low-temperature and high-temperature groups. The greatest lack of correlation is in the middle of the series in the 58° and 59° groups, which show a tendency toward higher sugar and acid content than do the groups on either side. This is not sustained in the higher groups, the 63° and 64° groups showing no indication that their composition has been affected by a seasonal temperature near their optimum in a manner different from the other groups.

CHARACTER OF THE 1920 CROP

The year 1920 ranked next to 1924 in the number of varieties having low sugar content in the large group. In that study very nearly all the varieties analyzed in the two years had their minimum sugar and cane-sugar content for the whole period in one or other of the two years, but in greatest numbers in 1924. The summation in Table 6 shows that the number of absolute minima for sugars and acids were much less than in 1924. There are a number of next to minimum values in 1920 in the groups analyzed in four or more years, with minimum values occuring in 1924, and minimum and next to minimum values taken together predominate over higher amounts, except in the case of acidity. There is no marked difference between the results in the high-temperature and the low-temperture groups in these respects.

TABLE 6.—*Number of varieties in the various temperature groups having minimum total sugar, sucrose, and acid content in 1920 (data on astringency not obtained)*

Group (°F.)	Number analyzed in 1920 and in one or more other years	Number showing in 1920—		
		Minimum total sugar	Minimum sucrose	Minimum acid
52	1	0	1	0
53	2	1	1	1
54	4	0	2	1
55	2	0	1	0
56	6	3	3	1
57	6	1	3	0
58	4	2	2	1
59	2	1	2	1
60	2	0	1	1
61	2	2	2	0
62	None.	0	0	0
63	1	0	0	0
64	2	1	1	0
65	1	0	0	0
66	None.	0	0	0
67	None.	0	0	0
Total	35	11	19	6

Taken collectively, 1924 and 1920 have nearly all the minimum values found at any time for total sugars, sucrose, and acidity for the varieties analyzed in these years regardless of the temperature groups to which they are assigned. Further, a very large majority of the varieties analyzed in 1923 and 1921 have the maximum amounts

of these constituents found at any time in one or the other of these years. This is merely another way of saying that all the varieties examined respond to the climatic conditions of the successive years in the same general way. The year having most favorable conditions for photosynthetic activity is the year having the largest number of maximum values for sugars and a considerable number of next to maximum values. The year which was next in rank with respect to conditions for photosynthesis was second in number of maximum sugar values, with a very considerable number of next to maximum values. The two years which were least favorable for photosynthetic activity are those characterized by the occurrence therein of minimum and next to minimum values for sugars and acid in nearly all the varieties analyzed in these years. Members of the low-temperature groups behave exactly as do those of the high-temperature groups in this respect. The exceptions to this general situation are so few that they can be named: Arkansas Black of the 63° group has minimum sugar in 1923; King David of the 59° group and Gano of the 64° group in 1921; Scott Winter of the 54° group and Sutton of the 56° group have maximum sugar in 1924, while Dudley of the 53° group and Golden Sweet and Swaar of the 58° group have maximum sugar in 1920. These are so few in number and so scattered throughout the whole extent of the groups as to be entirely without significance.

CHARACTER OF THE 1922 CROP

In the study of effect of climatic conditions on composition, the years 1922 and 1925 were found to be characterized by absence of either maximum or minimum contents of sugar, acid, and tannin. This is the general situation in 1922. Of the 78 varieties analyzed in that year, 60 were analyzed in at least two other years. Examining the data for these, it is found that only two of the 60 had maximum sugar, Gideon of the 54° and Haas of the 59° group. A number had their minima, McMahon of the 55° group, McIntosh and Wealthy of the 56° group; Babbitt, Boiken, and Jefferis, 57°; Red June and Swaar, 58°; Delicious, 59°; Fallawater, 60°; Ortley, 61°; Ingram, 62°; Oliver Red, 64°; Collins, 65°; and Terry, 67°. The distribution of these 15 varieties through all the groups makes it clear that the conditions of the year had no specific depressing effect upon sugar formation and storage in any particular temperature group.

CHARACTER OF THE 1925 CROP

Of the 44 varieties analyzed in 1925, 43 had been analyzed in at least two other years. Thirty of the number show values for sugars intermediate between the high figures found in 1923 and 1921 and the low figures found in 1924 and 1920. The remaining 13 are divided between the two extremes. Six had the highest sugar content found in any year in which they were analyzed. These are McMahon of the 55° group; Northern Spy, 56°; Monmouth and Roxbury Russet, 57°; Mother, 58°; and Paragon, 64°. In this year, seven had the minimum sugar content found at any time. These were Walbridge of the 54° group; Scott Winter, 55°; McIntosh, 56°; Hubbardston and Williams, 57°; Kinnard, 59°; and Huntsman, 62°. Maximum and minimum values occur side by side throughout the

series of temperature groups in such a fashion as to forbid the conclusion that they are other than responses to uncontrolled nonclimatic factors affecting specific individuals and not a response to any generally operative factor such as the temperature of the season.

GENERAL DISCUSSION

It is clear from the foregoing analysis of the results that the various groups of apples behaved in very large measure as a unit with respect to the composition of the crop throughout the period of observation. Two years having mean temperatures differing considerably—1923 with 65.4° and 1921 with 68.2°—are years characterized by high total sugar, sucrose, and acid content in a very large majority of varieties irrespective of the temperature groups to which they have been assigned. Varieties with a maximum in one of these years quite generally show next to maximum figures in the other. On the other hand, the two years having the minimum temperatures occurring during the period—1920 with 64° and 1924 with 62.9°—are characterized by low content of sugars and acid in a large majority of the varieties analyzed. Most of these, high-temperature and low-temperature varieties alike, show a minimum in one of the years and next to minimum in the other. Exceptions to these general statements occur in some numbers, but the departures from the general mass level occur in both directions and in all temperature groups, thus definitely disposing of any possibility that they can be due to the operation of a single factor.

In all that has been said thus far the comparison of the crops of the several years has been based upon the analytical data on the assumption that the amounts of total sugars, sucrose, acid, and tannin present in the expressed juice of a variety in any year is an index of the quality of the crop, as compared with similar analyses of the same variety in other years. It has already been pointed out that this is a legitimate assumption and that to deny it amounts to denying that chemical composition and quality have any discoverable relation. But there is considerable collateral evidence as to the comparative dessert quality and storage behavior of the crops of the years under discussion.

Representative tree-run samples of the crop, not only of the varieties here employed but also of all the apples in the variety collection at Arlington, have been examined by H. P. Gould, of the Office of Horticulture, each year, beginning with 1922. It has been Gould's custom to make somewhat full notes upon the individual varieties as they are inspected each year. These notes deal with size, color, texture of flesh, and dessert quality, primarily in comparison with his conception of the variety as such conception has taken form in the course of 25 years of continuous observation and study which has thoroughly familiarized him with nearly all these varieties throughout their range. Gould has kindly permitted an examination of these records and has discussed with the writer his estimates of the character of the crops of the various years. In a very considerable number of cases his notes upon the 1923 crop comment upon the exceptionally fine color, finish, and dessert quality of the sample of a variety. Those upon the 1924 crop as frequently record the statement that the sample was deficient in

color, size, flavor, dessert quality, and in nearly all the attributes of typical well-grown specimens of the variety. In both years these comments are made upon varieties distributed throughout all the temperature groups. Gould summarizes his estimates of the crops of the two years by the statement that as a whole the fruit of the 1923 crop of the Arlington orchard was of materially higher quality than that of any other year covered by his notes, while that of 1924 was as a whole and with few exceptions markedly inferior in appearance, color, and quality. J. R. Magness, of the same office, who has employed a considerable number of the more important commercial varieties in storage experiments during the years in question, states that the 1923 fruit was normal in its storage behavior, while that of 1924 was decidedly inferior in keeping quality, breaking down prematurely and failing entirely to develop the normal dessert quality of the variety. The independent judgments of these two gentlemen, therefore, support and confirm estimates of the character of the fruit based upon the results of comparison of the analytical data.

It appears from the data here presented that mean summer temperature is not the sole or dominant factor in determining the performance of trees during a season, as measured by the composition of the fruit. It is not possible to find any definite or consistent relationship between the amount of heat received in any season and the chemical composition of the fruit which indicates that any group of varieties has a fixed response to a definite seasonal temperature. On the contrary, the chemical results throughout the groups are in the great majority of cases directly opposite to expectation based on the assumption that temperatures control chemical composition. The normal mean summer temperature at Washington practically coincides with the highest temperatures of Shaw's groups. In consequence, most of the groups are growing under conditions in which they receive 2 to 10 degrees of heat daily in excess of their supposed optima. In accordance with theory, an excess of 2 degrees over the optimum temperature results in very evident alterations in size, form, coloration, and storage behavior as well as in chemical composition and quality. If this be true, varieties of the low-temperature groups, those with optima of 52° to 60° F., for example, should show consistent, rather wide departures from their normal character and composition year after year. In years of excessively high temperatures, as 1921, they should depart still further from normal, and such departures should become evident at higher levels in the ascending scale of temperature groups. In years of subnormal temperatures, as 1920 and 1924, the opposite result should be observed. Groups with optimum temperatures near that actually occurring in the season should be enabled to attain their optimum development; low-temperature groups should show smaller departures from the normal, while the high-temperature groups should be adversely affected by the lower temperatures.

But the actual results entirely fail to bear out these assumptions based on the optimum-temperature theory. Low-temperature varieties develop maximum sugar in the hotter years and minimum sugar in the cooler years, just as do the high-temperature varieties. It would be entirely impossible, from examination of the analyses of any year, to assign the varieties concerned to their respective tem-

perature groups, or even to say that any given variety belonged to a group having an optimum temperature above or below that of the year in question. It would also be impossible to examine the analyses of the members of any temperature group over a series of years and reach therefrom any correct conclusions as to the temperature conditions, considered separately and apart from the general climatic complex, in the various years. On the contrary, one would be led by the theory to consider the temperatures of the various years as opposite to what they actually were.

These facts would appear to make necessary some modifications of the theory of optimum temperatures. Chandler (*3, p. 589*) has said, in commenting upon the classing of varieties into temperature groups:

> While the fine discriminations of the table may not be justified, we can be reasonably certain that the varieties toward the top of the table are adapted to a low mean summer temperature, and those toward the bottom to a high mean summer temperature.

This statement, in which low-temperature and high-temperature groups are referred to as standing, respectively, toward the top and bottom of the table, can not be seriously questioned by anyone. But the individual variety, in the light of the results here reported, appears to be highly plastic in so far as adaptation to considerable variations in amount of seasonal heat received is concerned. Departures from the supposed optimum are not followed by definite and constant departures from normal composition. Heat-loving and cold-loving varieties behave as do those native to the latitude of the experiment; the chemical composition of their fruit in any season is a measure of the opportunity for photosynthetic activity afforded by the season, and there is no evidence that one differs from another in ability to utilize such opportunity. The results presented in the present paper and in accompanying papers show very clearly that throughout large groups of varieties there is a very considerable range of variation from year to year in the composition of the fruit of the same trees, and that these variations take the form of mass movements, large groups of individuals behaving as one. It has been shown that the direction and character of these mass variations are definitely related to the climatic conditions of the season, but the determining factor in the climatic complex is not temperature alone. Temperature enters into the results as a factor of secondary importance to sunshine, since the amount of sunshine is a direct measure of the opportunity for photosynthetic activity afforded by the season. In the latitude of Washington, these variations in chemical composition of the crop are striking both as regards their absolute and their relative amounts, and their range is as wide in varieties supposedly perfectly adapted to the region, such as York Imperial and Lawver, as it is in varieties from the extreme northern and southern limits of commercial apple growing, such as Arctic or Dudley and Buckingham or Terry. Further, the variation in total sugars, sucrose, and acid occurring in the fruit of the same pair of trees at Arlington in the course of five or six years, in the case of the varieties studied by Shaw, is as great as he found it to be in fruit collected in one or two years over the entire commercial range of the variety. The chemical differences found by Shaw between York Imperial grown in Kansas, Tennessee, and Massa-

chusetts are not so wide as those between the crops of the Arlington trees in 1923 and 1924. His samples of Baldwin from Amherst, Mass., showed nearly as large a range in sugar content as did those from Ohio, Kansas, New Hampshire, and British Columbia, and all of them fell markedly below the 1923 and 1921 crops at Arlington despite the fact that the Arlington temperatures in these years were 9.5 and 12.2 degrees, respectively, above the supposed optimum for Baldwin. The Arlington samples ranged from 10.11 per cent total sugar in 1920 to 14.96 per cent in 1923, the Amherst samples in 1910 from 7.90 to 10.64 per cent, and those from five other States and British Columbia from 7.86 to 11.79 per cent. Hence all the differences in soil, culture, and climatic conditions represented by samples collected over a wide area are productive of smaller differences in sugar content than are found in the fruit of a single pair of trees when analyses are continued through a series of years of rather widely varying seasonal conditions.

There is nothing in the vegetative behavior or in the fruitfulness of any of the groups of varieties here studied that can be considered clearly indicative of any marked lack of adjustment to the conditions of the locality. With respect to the composition of the fruit, the variations which occur from year to year are definitely related to the climatic conditions of the various seasons, and all the varieties studied behave as a unit in the direction, extent, and character of the chemical modification produced by a given set of seasonal conditions. All the varieties, high-temperature and low-temperature groups alike, produce their best crops under the seasonal conditions which afford greatest opportunity for photosynthetic activity, their poorest crops under the least favorable conditions for such activity. If excess temperature were acting as a limiting factor in the case of a part of the varieties employed, the degree of uniformity of physiological response shown by the analyses could not be expected to occur. That it does consistently occur would seem to make it clear that the exact adjustment of varieties to definite quantities of summer heat postulated by the optimum-temperature theory does not exist. Instead, most apple varieties have such a capacity of adaptation to varied climatic conditions that they can attain normal development under quite varied summer temperature conditions, subject only to the limitations upon such development resulting from the variations in seasonal conditions which occur from year to year.

SUMMARY

The optimum-temperature theory as applied to the development of apples asserts that mean summer temperature is the dominant factor of climate which determines quality in apples. It assumes that apple varieties have such exact adaptations to climatic conditions that any variety can attain its optimum development only at a certain definite mean summer temperature, exhibiting definite physical and chemical departures from normality with consequent lowering of quality when grown at temperatures above or below this optimum.

Ninety-eight varieties of apples belonging to 16 groups having supposed temperature optima from 52° to 67° F., inclusive, grown together under uniform controlled conditions at the Arlington

Experiment Farm, Rosslyn, Va., near Washington, D. C., under an average mean summer temperature of 64.5° have been studied over a period of six years. The accumulation of analytical data upon the composition of the fruit has been accompanied by a study of the climatic conditions of the years covered by the work.

As the mean summer temperatures at the Arlington farm very closely approximate the optima for the high-temperature groups but very greatly exceed those for the low-temperature groups, the optimum-temperature theory would assume that there would be a very decided contrast in the results observed with the two groups. Varieties of the low-temperature groups should display marked inability to attain normal chemical composition and dessert quality, while the varieties of high-temperature groups should attain a development very close to the optimum for the respective varieties. No such contrast appears in the results.

Mean summer temperature as a separate factor has little influence in determining the composition of the crop. The chemical character of the crops of the low-temperature groups in the warmest year (1921) and the coldest year (1924) are exactly the opposite of expectation based on the assumption that temperature is the dominant factor in determining composition. Years of closely identical mean summer temperatures show very considerable differences in the chemical character of the crop.

The composition of the fruit of all varieties shows considerable variations from year to year. The direction and extent of these variations are determined by the opportunities for photosynthetic activity afforded by the conditions of the season, and in responding to the seasonal conditions all the varieties, high-temperature and low-temperature groups alike, behave as a unit. Climatic conditions favoring the attainment of high quality as measured by total sugar, sucrose, acid, and astringency content in one group favor the attainment of a like condition in all groups regardless of their supposed temperature adaptations. Conditions which depress quality as measured by these constituents in one group exert a like depressing effect upon all groups.

The series of years covered by the experiment present an exceptionally wide range in the extremes of seasonal conditions which have occurred in them. Throughout the whole period, all the varieties included in the study have shown a high degree of uniformity in their behavior. In rate of growth, vigor, and health of tree, fruitfulness, and composition of the fruit there have been no indications that any of them were out of adjustment with the environment.

Varieties of the apple possess much greater capacity of adaptation to varied summer temperature conditions than is assumed by the optimum-temperature theory.

LITERATURE CITED

(1) CALDWELL, J. S.
1928. CHEMICAL COMPOSITION OF APPLE JUICES AS AFFECTED BY CLIMATIC CONDITIONS. Jour. Agr. Research 36:289–365.

(2) ———
1928. THE CHEMICAL COMPOSITION OF AMERICAN-GROWN FRENCH CIDER APPLES AND OTHER APPLES OF LIKE CHARACTER. Jour. Agr. Research 36:391–406.

(3) CHANDLER, W. H.
[1925.] FRUIT GROWING. 777 p., illus. Boston, New York [etc.].
(4) FRASER, S.
1924. AMERICAN FRUITS, THEIR PROPAGATION, CULTIVATION, HARVESTING AND DISTRIBUTION. 888 p., illus. New York.
(5) GARDNER, V. R., BRADFORD, F. C., and HOOKER, H. D.
1922. THE FUNDAMENTALS OF FRUIT PRODUCTION. 686 p., illus. New York.
(6) LEHENBAUER, P. A.
1914. GROWTH OF MAIZE SEEDLINGS IN RELATION TO TEMPERATURE. Physiol. Researches 1: 247–288.
(7) LIVINGSTON, B. E.
1916. PHYSIOLOGICAL TEMPERATURE INDICES FOR THE STUDY OF PLANT GROWTH IN RELATION TO CLIMATIC CONDITIONS. Physiol. Researches 1: 399–420.
(8) ——— and SHREVE, F.
1921. THE DISTRIBUTION OF VEGETATION IN THE UNITED STATES, AS RELATED TO CLIMATIC CONDITIONS. 590 p., illus. Washington, D. C. (Carnegie Inst. Wash. Pub. 284.)
(9) SEARS, F. C.
1917. PRODUCTIVE ORCHARDING. Ed. 2, 315 p., illus. Philadelphia and London.
(10) SHAW, J. K.
1910. VARIATION IN APPLES. Mass. Agr. Expt. Sta. Ann. Rpt. 22: 194–213, illus.
(11) ———
1911. CLIMATIC ADAPTATIONS OF APPLE VARIETIES. Mass. Agr. Expt. Sta. Ann. Rpt. 23: 177–245, illus.

○